# World Resources 1986

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# World Resources 1986

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and

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The cover is a Landsat photo of mountains and agricultural land. Center pivot irrigation systems are visible in the upper right-hand corner. Photo courtesy of NASA.

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# Contents

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# Preface

*World Resources 1986* is intended to meet the critical need for accessible, accurate information on some of the most pressing issues of our time. Wise management of natural resources and the protection of environmental quality are intimately linked to vital objectives: alleviating poverty, achieving sustainable economic growth, promoting public health, coping with the pressures of rapid population expansion, and ensuring long-term political and economic stability.

With the surge of interest in resources and the environment has come a demand for reliable information and objective analyses of that information. At first, the information sought was mostly local: the impacts of pollution from an industrial facility, for example. Then, in the 1970s, attention shifted to the national level. Today, the focus is increasingly international: the loss of tropical forests and good farmland are problems on many continents; transboundary pollution, resource disputes between countries, and threats to the global commons all demand attention. International banks, multinational corporations, development assistance agencies, and relief and refugee organizations all confront issues rooted in resource use, environmental quality, and population pressures.

The famine in Africa and countless other situations large and small throughout the world confirm the need for a regular, global report addressing these issues. Our hope is that *World Resources 1986* and subsequent volumes will meet this need by:

- Supplying basic information and reliable, current data on international conditions and trends to a broad audience, and, by doing so, providing a common basis for discourse; and
- Presenting objective analyses that are essential for identifying priority issues, resolving disputes, and formulating wise policies in the public and private spheres.

The task we undertook was ambitious and complex. By pooling the expertise of our two institutions and drawing on experts from around the world, we are confident that we are on the right road. If this report leads to improved understanding and action, and to a demand for more reliable and complete data in the future, we shall be well satisfied. And we are confident that, as with many undertakings of this type, subsequent volumes will improve on the shortcomings of the first.

There are many people to whom we are indebted and without whom *World Resources 1986* could not have been published. The *World Resources* staff, led in the final critical months by WRI Vice President, Dr. Jessica T. Mathews, deserves first mention; a more dedicated group would be hard to find. The Editorial Advisory Board, chaired by Dr. M.S. Swaminathan, was a steady source of encouragement and advice. One member of this board, Robert S. McNamara, deserves special mention for his original suggestion to produce a report of this type. Numerous collaborators and reviewers, both within and outside our two organizations, made valuable contributions. They are listed in the Acknowledgments.

We wish to note our deep appreciation of those organizations that support this effort financially: The Ford Foundation; the United States Agency for International Development; The J.N. Pew Jr. Charitable Trust; the John D. and Catherine T. MacArthur Foundation; the United Nations Environment Programme; The German Marshall Fund of the United States; The William and Flora Hewlett Foundation; The World Bank; the United Nations Development Programme; and the United States National Aeronautics and Space Administration.

A final note. Readers of *World Resources 1986* will see immediately that it addresses some of the most heartrending and disturbing issues of our time. There have been solid successes and great failures in dealing with these issues. The experience of the last two decades provides ample grounds for both optimistic and pessimistic assumptions about the future. Clearly, the challenges described in this volume will be met only if concerted efforts are made, with some urgency, to change many current policies, to strengthen and multiply successful initiatives that have been taken, and to carefully exploit emerging technologies. Realizing a brighter future will require both energetic initiatives by governments and larger roles for those outside government, including private business, the scientific community, and non-governmental organizations of all types. Our hope is that *World Resources* will facilitate such a response.

**Brian W. Walker**
President
International Institute for Environment and Development

**James Gustave Speth**
President
World Resources Institute

# Acknowledgments

We are indebted to a host of people who contributed to making *World Resources 1986* a reality. First and foremost are those who, early in the project, shared our view that this would be a worthwhile undertaking and provided the financial support to make it possible. We thank: The Ford Foundation; the United States Agency for International Development; The J. N. Pew Jr. Charitable Trust; the John D. and Catherine T. MacArthur Foundation; the United Nations Environment Programme; The German Marshall Fund of the United States; The William and Flora Hewlett Foundation; The World Bank; the United Nations Development Programme; and the United States National Aeronautics and Space Administration.

Our colleagues at the International Institute for Environment and Development and at the World Resources Institute ungrudgingly interrupted their own work time and again to answer our pleas for advice and criticism. They drafted, reviewed, corrected, found leads to new material, and in general provided invaluable assistance. Without their help it could not have been done. We are deeply grateful to them all.

Several writers and technical experts assisted in the actual drafting of chapters. They are: Libby Bassett (Policies and Institutions), John Beddington (Oceans and Coasts), Mark Bello (Human Settlements), Chris Bernabo (Atmosphere and Climate), Nora Berwick (Oceans and Coasts), Malin Falkenmark (Freshwater), John Gulland (Oceans and Coasts), Jorge Hardoy (Human Settlements), Peter Harnik (Food and Agriculture), Frank Hebard (Oceans and Coasts), William Lanouette (Policies and Institutions), Norman Myers (Wildlife), Margie Patlack (Oceans and Coasts), Jeannie Peterson (Population), Richard Sandbrook (Policies and Institutions), David Satterthwaite (Human Settlements), Napier Shelton (Wildlife), Dean Treadwell (Forests and Rangelands), and Robert Winterbottom (Forests and Rangelands). Responsibility for the chapters as they now appear rests with the *World Resources* staff, but each of these individuals shares substantial credit for what is new, valuable, and insightful in this book.

Dozens of individuals in universities, governments, international organizations, research institutions, and elsewhere generously provided data (some of it not previously published), reviewed drafts, or wrote short sections. The length of the list does not diminish their individual contributions or our gratitude to each of them. They are: Christian Averous, Silvio Barabas, Geoff Barnard, Peter Bartelmus, Ann Bartuska, Burton Bennett, David Bennett, Nancy Birdsall, Helen Bothwell, Marcia Brewster, Harrison Brown, Lester Brown, Robert Bruck, Sharon Camp, Frank Carter, Ramesh Chander, Garry Charnock, Wan-li Cheng, Thomas Conway, Ken Cook, Cliff Curtis, Ellis Cowling, Julio Davila, J.L.T. Davies, Annick de Marffy, Louis DeMouy, Robert Dickinson, David Flood, Robert Fox, Fritz Fuhr, Silvio Funtowicz, William Geddes, Katherine Gillman, John Gladwell, Roger Goss, William Gregg, Elizabeth Gormley, Gunnar Hagman, Andrew Hamer, Jeremy Harrison, Carl Haub, Howard Hogg, Martin Holdgate, Bruce Horwith, Robert Johnston, Andreas Kahnert, John Kammerer, Charles Keeling, Lee Kimball, Glenn King, Reiner Kramer, Christine Kronauer, Hans Landsberg, Wo Yen Lee, Maureen Lewis, James Listorti, Eduardo Loayza, James MacKenzie, Gordon Mackerron, James MacNeill, Arthur McKenzie, Jean Margat, Joan Martin-Brown, Elaine Matthews, Tom Merrick, Hugh Miall, John Miller, Lawrence Minear, Liz Mills, Peter Odell, Phil O'Keefe, Wallace Parham, David Pearce, J.B. Penn, Arthur Purcell, Leroy Quantz, Bernhard Rami, J.R. Ravetz, John Reuss, Jane Robertson, Ralph Rotty, Francesco Sella, Peter Schutt, John Scott, Alfredo Sfeir-Younis, Jose Shapouri, Alec Dawson Shepherd, Mary Stafford Smith, Richard Smith, Rezso Solymos, Odyer Sperandio, Patricia Strauch, Thomas Stoel, John Surrey, Jane Thornback, Vladimir Uspensky, Carl von Hake, Howard Walton, Phillip Wardle, Greg Watters, Susan Wells, Edward Wolf, and William Zajac.

Producing this volume was a gargantuan task. Mary Paden, our Production Manager, led a talented and dedicated team of copy editors, fact checkers and proofreaders who worked long and unpredictable hours: Katherine Hoskins (who also produced the Index), Esther Runnalls, Sheila Mulvihill, Richard Danca, Leslie Lin, Diana Field, and Anne Norman. Novella Murray, Project Secretary, supervised a superlative team, including Evelyn Bland, Carlton Marbley, Harristeen Soard, and Linda Swerdloff, who endured a grueling work schedule. Maurice Allen and intern Susan Warford were indispensable in helping to prepare Part IV. We thank them all for their commitment, skill, and high professional standards.

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J.T.M.
D.H.

# Note to the Reader

This is the inaugural volume of an annual series. It does not, therefore, try to cover all the important topics in the vast field of resources and the environment. Readers surprised by the absence of a particular subject should be reassured: it will appear in a subsequent volume.

For example, this year's Chapter 2, on "Population," focuses on the basic determinants of growth: fertility and mortality. Next year's chapter will deal with aspects of health and nutrition. In this edition, Chapter 3, "Human Settlements," discusses urban life. Subsequent editions will cover rural settlements, land tenure, and other issues not treated here. Chapter 6, "Wildlife and Habitat," explores topics related to endangered species and ecosystems and various means of protecting them. Very different issues will appear subsequently—from the management and economic use of wild species to advances in biotechnology and their implications for wildlife. This year, Chapter 9, "Oceans and Coasts," covers fisheries and three important coastal ecosystems. Next year's chapter will treat marine pollution. And so on.

Beginning next year there will be an additional chapter on biogeochemical cycles. It will cover the emerging understanding of the global cycles of carbon, nitrogen, sulfur, phosphorus, and methane, how they affect life on Earth, and people's role in altering them.

A characteristic feature of environment and resource issues, as it is of most living systems, is that everything is connected to everything else. Consequently, there is no wholly satisfactory way to organize a volume such as this: any plan creates artificial divisions. For example, Chapter 8, "Freshwater," treats water as a resource. But water's principal use, irrigation, is also covered in Chapter 4, "Food and Agriculture," because irrigation is a prime determinant of crop productivity. Many cross-references are noted in the text, but including them all would be disruptive. The reader is urged to consult the Contents and the Index as well.

Another characteristic of these issues, and a principal motive for undertaking this project, is the gaping holes in basic knowledge. In Chapter 5, "Forests and Rangelands," for example, the reader will discover that reliable data on the conditions of the world's rangelands simply do not exist. The very high failure rate of rangeland management projects is not unrelated, one suspects. Similarly, Chapter 9 in Part IV, "Freshwater," reveals how poor the data are even for such a basic resource as water. The best data on water availability are more than ten years old and are not reliable. Information on water quality and use is often worse: values for many basic indicators have not been measured, and those that have been measured are often not comparable among countries. At the present level of effort, it may take as long as a decade to establish reliable water quality trends for much of the world. We hope that *World Resources* will alert policymakers throughout the world to the limitations of existing data and to the pressing need for improvement.

There is no single theory or approach that can be used to identify the most important indicators of world resource use and environmental quality. Lacking one, we have tried in the Part IV tables to cover all major resources and to select a few data series that bear upon important policy issues for each. Their selection was heavily influenced by the availability of comparable data for most countries and of time series data. When the latter are not available, we include data on significant similarities and differences among countries and regions or make comparisons with established guidelines or standards.

Part IV is divided into 12 subject areas corresponding to the 10 in Part II, plus added chapters on "Economic Development" and "Land Use and Cover." Each chapter (except "Atmosphere and Climate") opens with a table that contains data for 146 independent countries and, where applicable, totals for continental groupings (including the Soviet Union) and for the world. (Countries with estimated 1985 populations of less than 240,000 people are omitted. Data for these countries are included in the continental and world totals.) Tables for each resource include the extent of the resource, the quality or condition of the resource, and its use or value. Statistics on per capita use or availability and other measures of distribution are often included.

By and large, this report covers the recent past and the present; it does not attempt to project the future. However, trends are presented and discussed, especially where projections have been the subject of intense study, as in the case of population and of energy.

We were aware from the start that this was an ambitious undertaking. Only a sense of its potential value—and the expectation of a partnership with a growing circle of users—led us to push ahead with the project. For *World Resources* to serve the needs of you, its readers, we must know what they are. What should be changed, strengthened, added, dropped? We welcome your suggestions and comments.

# 1. An Emerging Agenda

Among the hundreds of topics addressed in this volume, a number stand out, either because they demand urgent remedial action, because they are new problems that could heavily affect future environment or policy, or because of their pervasive impact on the human condition. We have chosen several to review here, highlighting key points from Parts II, III, and IV. They illustrate how the subjects treated in separate chapters are in fact bound in an indivisible web of cause and effect and, we hope, suggest the depth and scope of the material to be found in the rest of the volume.

Because the purpose of *World Resources* is to contribute to better management of the environment, the emphasis here is on problems—situations that call for attention and action, whether it be research, data collection, applying proven management strategies, or adopting new policies. This does not mean that conditions everywhere are worsening, or that the future will necessarily be gloomy. The problems are eliciting some positive responses, many of them described in the Recent Developments sections of this book and in Chapter 11, "Policies and Institutions", that could substantially alter present trends. Mankind today has unprecedented wherewithal to determine its future circumstances—for better and worse. Notwithstanding the formidable challenges posed by population growth, widespread resource degradation, and diverse sources of pollution, there are few, if any, problems on the horizon that are in any fundamental sense unsolvable.

## THE ENVIRONMENT AND HUMAN HEALTH

Environmental quality and successful resource management affect human health far more than is widely recognized in a world where "health care" is so often equated with "medicine," and high technology medicine, at that. Yet the demographic transition from high to low mortality rates in the developed countries generally predated the availability of specific therapies. It came with the advent of basic environmental amenities: clean water and sanitation, and improved nutrition and living conditions. (See Chapter 2, "Population": The Demographic Transition, Figure 2.7, and Box 2.1.)

Medicine, principally vaccines and antibiotics, has been a significant factor in the much sharper declines in mortality rates in today's developing countries, but the dominant role is still played by improved living—that is to say, environmental—conditions. The biggest drop in mortality has come in the shaky first year of life. Despite the rapid improvements of the past three decades, however, infant mortality is still one of the clearest measures of the gap between developed and developing countries; it ranges from fewer than 1 percent of live births in many western European countries to more than 15 percent in some Asian and African nations. (See Chapter 2, "Population": Infant Mortality Rates, and Box 2.2; and Part IV, Table 2.4.)

The availability of sufficient food is the first requirement for a healthy life. Despite steady worldwide gains in agricultural production through the decade, the grim fact remains that there were more hungry and malnourished people in 1980 (*before* the African drought) than there had been ten years earlier. In 1980, excluding China, 700—800 million people ate fewer than 90 percent of the calories international standards deem necessary for an "active working life." Of these, about half ate fewer than 80 percent of the standard, an insufficient number of calories to prevent "stunted growth and serious health risks." Poverty and misguided government policies, not inherent resource limitations, are the reasons for this growing hunger in a world of agricultural surpluses. The ties run in both directions. Past resource degradation deepens today's poverty, while today's poverty makes it terribly hard to care for or restore the agricultural resource base; to find alternatives to, or carefully manage, deforestation; to prevent desertification; to control erosion of irreplaceable topsoil; and to replenish soil nutrients. (See Chapter 4, "Food and Agriculture": The Resource Base, and Table 4.1.)

A sufficient calorie supply is not all that is necessary for adequate nutrition: clean drinking water is also essential. Chronic intestinal infections from contaminated water cause malnutrition in thousands upon thousands of towns and villages where there is enough food. Throughout the developing world, water polluted by sewage or industrial wastes causes disease and death. In India for example, 70 percent of all surface waters are polluted. As the Yamuna River flows through Delhi, it picks up a staggering *daily* load of 200 million liters of untreated sewage and 20 million liters of industrial wastes (including 500,000 liters of DDT wastes). Overall, four out of five people in the developing countries had no sanitary facility—not even a pit or bucket latrine—in 1980. The same proportion—80 percent—of childhood deaths is due to water-borne disease. Ironically, many of the disease vectors flourish in the standing water of irrigation systems created to aid food production. Water shortages are also a major cause of suffering and death. Sometimes they are the result of a drought or other natural disaster, but often there are human causes: the disruption of hydrological cycles by deforestation and loss of soil cover, over-use of groundwater, or excessive erosion. Together, water shortage and contamination cause 25,000 human deaths daily. (See Chapter 8, "Freshwater": Public Water: Drinking Water and Sanitation, Water Pollution, and International Drinking Water and Sanitation Decade.)

Environmental impacts on human health are widely felt in the developed world as well. There, pollution, more often than resource degradation, is the culprit. Air pollution standards, based on demonstrated harm to human health, are exceeded all over the world. While the trends for regulated pollutants such as sulfur dioxide, suspended particulate matter, nitrogen oxides, and carbon monoxide are generally improving in the developed countries, a host of potentially serious health problems remains. Among these are the effects of nitrogen oxides, which may be more serious than yet recognized; the still uncontrolled status of fine particulate matter; and unregulated trace emissions of organic compounds, toxic metals, and fibers, which may be causing cancer, birth defects, and other disease. (See Chapter 10, "Atmosphere and Climate": Emissions and Ambient Air Quality, and Problems Remain.)

While the quality of surface waters in the Organization for Economic Co-operation and Development (OECD) nations is generally improving, the pollution of groundwater by human wastes and toxic chemicals is a growing concern. In the United States alone, 1,000–2,000 hazardous waste dump sites are considered potential threats to groundwater reserves. Once groundwater is contaminated, it can take decades, centuries, or even longer before natural processes eliminate the pollution. (See Chapter 8, "Freshwater": Groundwater.)

Other environmental threats to human health have been largely ignored in developed and developing countries alike. Pesticides are a striking example. Despite more than three decades of rapid growth in pesticide use, astonishingly little is known about their effects on the health of those who labor in the fields. Reliable data on rates of poisonings and death do not exist, though more than enough is known to warrant serious concern. Even when a pesticide has been identified as dangerous and banned in some countries, its use may continue and even spread in others. In fact, in 1979 nearly one-third of the pesticides exported by the United States were not registered for use at home, and of these, 20 percent had been canceled or suspended by the government as unsafe to human health or the environment. (See Chapter 4, "Food and Agriculture": Pesticides.)

This is no more than a sampling of the myriad ties between environmental quality and human health. Despite dramatic progress in some regions, pollution of air, water, and soils still poses significant known and potential health threats. But the lack of adequate nutrition, of potable water, and of sanitation remain the principal causes of human ill health in the world today, all of them in the purview of environmental and resource policy, not of medicine.

## TROPICAL DEFORESTATION

The picture that tropical forests present of dense, almost uncontrollable growth is deceptive. In part because of their tremendous genetic richness, these forests are actually an extremely fragile ecosystem, highly susceptible to damage from human activities. Once damaged, the entire ecosystem can quickly unravel in a now all-too-familiar sequence: interruption of nutrient cycling; loss of soil fertility; extinction of plant and animal species; soil erosion; downstream siltation, flooding, and damage to irrigation systems; and (especially in the dry tropical forests) acute fuelwood shortages. The effects ripple through agriculture, energy supply, water quality, and nearly every aspect of the daily life of 1 billion people. The end result is biological impoverishment and human suffering writ large.

Exactly how fast the tropical forests are disappearing has been hotly debated, party because of the use of differing definitions of deforestation. Some statistics reflect only complete forest loss, while others measure the partial damage caused by such activities as selective logging, road building, grazing, and fuelwood gathering. The bottom line is that somewhere between 25–40 percent of the original extent of the tropical forests was lost by 1980. The best current estimate is that about 80,000 square kilometers—an area the size of Austria—is lost, that is, converted to non-forest uses, each year. About one-and-a-half times as much is damaged to some degree. By the year 2000, if current trends continue, about 12 percent of the moist tropical forests that remained in 1980 will be gone, as will slightly less—about 10 percent—of the remaining dry tropical forests. Rates of loss vary enormously among countries, and none of the data are as good as they should be, but the overall trend and its gravity for mankind are beyond question. (See Chapter 6, "Wildlife and Habitat": How Many Species?, Extent and Condition of Ecosystems; and Chapter 5, "Forests and Rangelands": Focus on: Deforestation in Developing Countries.)

Most immediately, the continuing loss of these forests spells the disappearance of much of the planet's biological diversity. Though today's tropical moist forests cover only about 7 percent of the earth's land area, they are believed to be home to half of its species. No other ecosystem rivals them in genetic luxuriance. Whereas a hectare of temperate forest might contain as many as 10–15 tree species, the same area of Amazonian rainforest might hold more than 200. Only 1.7 million of the planet's estimated 5–10 million species (the total may be double or triple that number) have yet been identified, so millions more remain to be found in the tropical forests. At current rates of tropical forest loss, then, a million species—10–20 percent of the earth's total—could become extinct by about the year 2000. Most will disappear without ever having been discovered. (See Chapter 6, "Wildlife and Habitat": Distribution and Diversity, How Many Species?, Extinction, and Table 6.2.)

What this means is that the planet will lose a sizable portion of its genetic heritage, and mankind a resource of immense—if immeasurable—value. The genetic ancestors of nearly all of today's agricultural crops are found in the tropics. Plant breeders must turn to these relatives for the genes necessary for pest- and disease-resistance, for other crop improvements, and for adapting present-day crops to changing conditions. Medicine relies on the forests as well: more than half of modern medicines come from plants, a great many of them tropical plants. Industrial products from the tropical forests include everything from rubber, rattan, turpentine, and bamboo to a galaxy of fibers, resins, steroids, and dyes. The psychological, cultural, and aesthetic value of the wildlife itself can be sensed, though not measured. (See Chapter 4, "Food and Agriculture": The Seed Wars; and Chapter 6, "Wildlife and Habitat": Species.)

The pressure of growing populations on the dry tropical forests is creating a new energy crisis, even as the oil crisis recedes. Half the world's people depend on biomass energy—principally fuelwood—for their daily needs. About 60 percent of them, 1.5 billion people, are cutting wood faster than it can grow back, creating a fuelwood deficit that is expected to double by 2000.

The rural poor are the principal victims. As population densities rise, people are forced to shift from collecting and using dead wood to using grass, twigs, whole branches, and ultimately to chopping down entire trees. As supplies dwindle, the amount of time spent collecting a family's fuelwood rises to as high as 300 workdays per year. Economizing on the amount of wood used eases the shortage: people light smaller fires and quench and reuse the embers rather than letting them burn out. Surveys in Mali and Niger show annual fuelwood consumption as low as 500 kilograms per person per year, less than a quarter of that used in areas where fuelwood is more abundant. But there is a limit: the household fire supplies not only the energy to cook food and heat water, but also serves as a source of lighting and space heating, as an insect repellent and defense against wild animals, and as the focal point for family life. Nearly 100 million people in Africa cannot meet their minimum fuelwood requirements even by overcutting trees. (See Chapter 7, "Energy": Biomass Fuels, and Focus on: Fuelwood Scarcity; and Chapter 5, "Forests and Rangelands": Fuelwood Production.)

When wood supplies run out, people are forced to turn to the next available source, usually animal dung or crop residues. Here the effects of deforestation begin to touch agriculture, for dung is a valuable fertilizer, and the recycling of crop residues is essential for soil maintenance and protection against erosion. An estimated 400 million tons of dung are burned annually where fuelwood is scarce. The sacrifice of this fertilizer is estimated to depress grain harvests by over 14 million tons, an amount greater than annual food aid to all the developing countries. In China, which suffers from acute energy shortages in its rural areas, as much as 75 percent of available crop residues are used for fuel, whereas in the United States 70 percent are recycled. (See Chapter 4, "Food and Agriculture": Expanding the Cropland Base, and Focus on: Erosion.)

There are other impacts as well. Deforestation on steep upland watersheds leaves the unprotected soil to wash rapidly away, increasing siltation and causing flooding downstream. The useful life of expensive hydroelectric projects can be sharply curtailed as their reservoirs silt up. The Anchicaya Dam in Colombia, a not atypical example, lost 25 percent of its storage capacity in just two years because of deforestation in its watershed. Irrigation systems, another costly investment, can also be badly disrupted. (See Chapter 4, "Food and Agriculture": Focus on: Erosion.)

Taken as a whole, the rate of deforestation in the tropics exceeds the rate of reforestation by ten to twentyfold. Yet there are grounds for optimism about the future. Within the past few years, the fate of the tropical forests, once the concern of a relatively small community of conservationists and foresters, has become a focal point of activity for a rapidly expanding number of nongovernmental organizations and governmental agencies. Afforestation projects have become integral elements not just of forestry programs, but of broader programs designed to address desertification, water quality, erosion, energy shortages, and rural hunger. Citizen "grass roots" efforts have proliferated in everything from village tree plantings, to establishing seedling nurseries, promoting agroforestry, and pushing for the reform of government policies that intentionally or inadvertently encourage deforestation. There is not much time for these efforts to succeed. A far larger gathering of public support, national commitment and international assistance is urgently needed. (See Chapter 5, "Forests and Rangelands" Reforestation and Forest Renewal, Investment in Forestry: Priorities and Needs; and Chapter 11, "Policies and Institutions": Citizen Efforts and Public Support.)

## THE ATMOSPHERE AS A SHARED RESOURCE

Not long ago air pollution seemed a relatively well-defined environmental issue. A few air pollutants—sulfur dioxide, particulate matter, nitrogen oxides, and carbon monoxide—went up and then came down nearby, causing visibly dirty air, noticeable effects on human health, and sometimes a circle of dead or dying plants around the emissions source. Today the situation is very different. The number of pollutants demanding attention has multiplied. Emission sources and affected areas may be separated by hundreds, even thousands of miles, so that regulation is no longer a local or even a national matter, but often an international one. The atmosphere itself is no longer seen as simply the passive receptacle of pollution. Now it is understood to be an active participant in an extraordinarily complex set of chemical and meteorological interactions in which emissions are mixed, transformed, and transported. The continuity of the atmosphere has been further dramatized by the emergence of two *global* pollution problems—the greenhouse warming, and the depletion of stratospheric ozone—emphasizing the degree to which the atmosphere is a resource shared by, and perhaps someday to be jointly managed by, the entire planet.

Concern over acid deposition has been the prime mover behind the shift in attention from the local to the regional and international scale. As emissions of sulfur dioxide and nitrogen oxides travel long distances in the atmosphere, they are chemically transformed into sulfuric and nitric acids. These return to earth in rain, snow, fog, and mist, and as dry deposition. Emissions can remain in the atmosphere anywhere from hours to weeks, depending on meteorological conditions, and can therefore be transported quite far or hardly at all. In eastern North America and Europe, about one-third of deposited sulfur comes from relatively close by (less than 200 kilometers away), one-third from medium distances (200–500 kilometers), and one-third from long distances (more than 500 kilometers). Central Europe measures about 2,000 kilometers from the beaches of Normandy to the eastern edge of Czechoslovakia. In that space (and about half as far from north to south) there are about a dozen nations. Obviously, tracing responsibility for what comes down, as a prerequisite to regulating what goes up, is a difficult task; achieving effective control without international cooperation is impossible. (See Chapter 10, "Atmosphere and Climate": Transport of Atmospheric Pollutants.)

The exact degree of acidification an individual body of water will undergo depends on many local factors, including composition of bedrock, type of surrounding vegetation, time of year, forest-soil interactions and more. But these and other measures allow scientists to identify acid-sensitive regions. For example, Sweden estimates that about 40,000 of its 90,000 lakes are acid-sensitive. Of these, 4,000 are already highly acidified, 18,000 are partly acidified, and 20,000 are at risk if present trends continue. The country also has 90,000 kilometers of acidified streams. Damage to fish ranges from temporary disruption to the loss of whole populations. Similar situations exist in Norway, the United States, Canada and other countries. (See Chapter 10, "Atmosphere and Climate": Deposition, and Acidification of Aquatic Ecosystems.)

Acid deposition is also implicated in the far more complex phenomena that are damaging terrestrial systems, including soils, crops, man-made structures, and, especially, forests. In a broad swath of destruction, more than 7 million hectares of forests in 15 European countries have been stricken by a disease syndrome dubbed *Waldsterben* (forest death) that is thought to be caused by the actions of many pollutants acting in combination with biological and physical stresses (insects, fungi, weather, etc.) (See Chapter 12, "Multiple Pollutants and Forest Death": Box 12.1.)

Unlike previous forest declines, *Waldsterben* in Europe is neither localized nor limited to one or a few tree species. It affects nearly every important species in Central Europe, including types of spruce, fir, pine, beech, birch, maple and oak. (In the United States a related but distinct phenomenon is at work, so far affecting only conifers. See Table 12.2.) Once the signs of damage are visible, the syndrome can progress with devastating speed. Eight percent of West German forests were reported dead or damaged in 1982. One year later the figure was 34 percent. By 1984, the toll stood at 50 percent. (See Chapter 12: Introduction, Historic Forest Decline, and Table 12.3.)

The causes and mechanisms of *Waldsterben* are still so mysterious that the possible triggering agents include a long list of airborne suspects: ozone and other oxidants including PAN (peroxyacetyl nitrate) and PPN (peroxyproprionyl nitrate); total biologically-available nitrogen compounds; other plant-damaging gases such as nitrogen oxides, sulfur dioxides, and fluorine; toxic metals including lead, cadmium, zinc, and copper; acid deposition; and growth-altering organic chemicals. The symptoms of damage are so varied that ten different mechanisms involving these substances have been proposed. Other hypotheses suggest viral and other non-pollution-related causes. But increasingly the finger is being pointed at air pollution. Of the 19 regional forest declines in Europe and North America over the last 50 years, air pollutants are believed to have been the primary or contributory cause in at least seven. With one exception, all of these declines developed (or were first noticed) during the last eight years. (See Chapter 12: The Chemical Etiology of *Waldsterben*, and Historic Forest Decline.)

Despite the bewildering array of symptoms, scientists have managed to identify some characteristic features of the disease, including some that have never been described before. The pace of research in the past few years has been urgent, but as of this writing little is known with certainty. *Waldsterben* does seem to be a distinct phenomenon, unlike previous forest diebacks caused by pollutants, pathogens, or climatic stress, and it appears to be the result of multiple air pollutants acting additively or synergistically in ways yet to be deciphered. (See Chapter 12: Forest Damage, and The Burden of Research.)

Like *Waldsterben*, human impact on the stratospheric ozone layer has proven to be a particularly difficult phenomenon to understand. The principal causative agent is known: a group of very stable, and therefore long-lived, chemical compounds known as chlorofluorocarbons (CFCs) used primarily in aerosols, and refrigeration. The principal result—greater ultraviolet radiation from the sun reaching the earth—is also clear. The likely effects are less well known. An increase in non-melanoma skin cancer is generally agreed upon, while damage to plants and animals, suppression of human immune systems, an increase in skin melanomas and other possible effects are controversial. However, estimates of the *rate* at which the protective ozone layer is being depleted, and therefore of the urgency of the issue, have fluctuated for years as scientists have learned more about the many processes that determine atmospheric chemistry and climate. Depletion is no longer even the sole subject of study: the various effects on global climate of ozone's vertical redistribution now further complicate the picture. Recently, concern over the future of the ozone layer has grown (as, unfortunately, have emissions of CFCs) to the point that nations have undertaken an unprecedented negotiation to protect this global resource. (See Chapter 10, "Atmosphere and Climate": Potential Changes in Stratospheric Ozone, and Vienna Convention For the Protection of the Ozone Layer.)

Dwarfing even ozone depletion in its scope and complexity is the apparent greenhouse warming of the planet. Carbon dioxide emissions, principally from the combustion of fossil fuels, account for about half of the greenhouse effect. The other half is due to the combined role of many other gases, principally nitrous oxide, methane, CFCs, and tropospheric (lower atmosphere) ozone. These gases are transparent to most of the incoming radiation from the sun, but absorb the heat radiated back by the earth, thereby heating the atmosphere—hence the "greenhouse" effect. If present trends continue, the global average surface temperature is predicted to rise 1.5–4.5°C in less than 50 years. While no one *feels* an average global temperature, the effects on climate are expected to be most definitely noticeable, with possibly severe consequences for people and wildlife. A sea-level rise of uncertain magnitude is predicted, as are regional changes in rainfall, growing season, normal peak temperatures, and numerous other climatic characteristics. (See Chapter 10, "Atmosphere and Climate": Focus On: The Greenhouse Effect.)

The greenhouse warming, like stratospheric ozone depletion, has been termed a "planetary experiment," one so complex that nearly every prediction is uncertain. Unlike a scientist's tinkering, however, the outcome is one mankind will have to live with. Therefore, despite the daunting technical uncertainties, scientists are uncharacteristically calling on governments to consider greenhouse impacts as they plan future investments, and to begin an active collaboration between scientists and policymakers to explore alternative policies, especially in energy conservation, in order to slow, prevent, or adapt to a greenhouse-induced climate change. Success in these efforts will demand ideas as new—and a degree of international cooperation as unprecedented—as the phenomenon itself. (See Chapter 7, "Energy": Energy Projections; and Chapter 10, "Atmosphere and Climate": Box 10.1.)

## SOIL DEGRADATION

With more and more people on the planet, there is a constant search for new cropland. It is not easy to find. Areas with the greatest need tend to have the least available land. Land not being used generally has problems of soil type, climate, accessibility, or topography that severely limit its potential. Or it may have other uses, such as wildlife habitat, that must be sacrificed if the land is to be converted. Ten years ago, two-thirds of the population of the developing world already lived in countries rated "land scarce" or "extremely land scarce" (countries in which more than 70 percent of the potentially arable land is being cultivated.) By 2000, there is projected to be about half a hectare of cropland per person in the industrial market economies, about one quarter of a hectare in the centrally planned economies, and an average of 0.19 hectares per capita in the developing countries—only half that amount in East Asia. (See Chapter 4, "Food and Agriculture": Expanding the Cropland Base, and Table 4.2.)

Ironically, while the search goes on for new agricultural land, the existing crop and rangeland base in the arid and semi-arid regions is being steadily diminished because of changes that reduce or completely destroy its agricultural productivity. Collectively these changes are somewhat misleadingly called "desertification." The appearance and spread of sand sheets and dunes may be, but often is not, involved. Depending on the local environment and what it is being used for, impoverishment and loss of vegetation, soil compaction and loss of nutrients, soil erosion and salinization, and loss of surface water and ground water, may all be part of the process.

Desertification usually begins with a drying of the soil that results from excessive stress, for example from overgrazing rangeland. The native vegetation then declines, producing less organic matter to maintain soil fertility. The soil can become so hard that the heavy but infrequent rains characteristic of arid regions have no chance to percolate into the soil, where they could recharge underground aquifers and provide moisture to plants. Instead the water runs off, leaving behind the aptly-named "erosion pavement." In the late 1970s, a United Nations Study estimated that 40 percent of Africa's non-desert land was at risk of desertification, as was 32 percent of Asia's and 19 percent of Latin America's land. More recent studies have estimated the damage to the various major types of dryland: rangeland, rainfed cropland and irrigated lands. The total area involved is more than 3 billion hectares, almost one quarter of the earth's land surface. Of these, 60 percent of the rangelands and rainfed cropland are moderately to very severely desertified, as are 30 percent of the irrigated lands. The degrees of damage counted in these categories range from a significant loss of production potential to a total—and sometimes permanent—loss. (See Chapter 5, "Forests and Rangelands": Condition of Rangelands; Chapter 4, "Food and Agriculture": Expanding the Cropland Base; and Part IV, Table 6.3.)

Among the types of soil degradation included in the process of desertification, erosion is one of the most widespread, though it is certainly not limited to arid and semi-arid regions. Depending on local conditions, soil loss and new soil formation are approximately in balance at an erosion rate of about 0.5 to 2.0 metric tons per hectare per year. But agricultural activity, especially on steep slopes, pushes the erosion rate manyfold higher. As expanding populations in many countries push the poorest of the poor farther and farther up steep hillsides, erosion intensifies accordingly. For example, in Nigeria, test plots planted in cassava lost soil at the rate of three metric tons per hectare per year on nearly flat land. On a 5-percent slope the rate jumped to 87 tons, and on a 15-percent slope it rose to 221 tons, a rate that would remove all the topsoil in a decade. The lost soil may be carried away by wind or water. Scientists in Hawaii can tell when spring plowing begins in China because they see the dust over the Pacific. Water-borne erosion can be equally dramatic: China's Huang River is the most sediment-laden in the world. In some stretches it is about 50 percent silt by weight—just under the level classified as liquid mud. (See Chapter 4, "Food and Agriculture": Focus on: Erosion; and Part IV, Table 5.)

Because erosion is so dependent on site-specific conditions, and because it is often studied where conditions are worst, national rates have to be treated with great caution. Nonetheless, they suggest the dimensions of a severe problem. Haiti and Nepal are familiar examples of extreme erosion, but there are many others. In Guatemala 40 percent of the land's productive capacity has been lost to erosion. In Turkey 75 percent of the land is affected, more than 50 percent of it severely. In India 13 million hectares are eroded by wind and 74 million by water, an astonishing one-quarter of the country's land area.

One reason erosion is so difficult to control is that many of its most costly impacts occur miles from the eroding field. In the United States, for example, the annual *off-site* costs of erosion are estimated at $6 billion in damage to fish and coral reefs, loss of hydropower potential, loss of storage capacity in reservoirs, and need for dredging of rivers and harbors. (See Chapter 4, "Food and Agriculture": Focus on: Erosion.)

Like erosion, the salinization and waterlogging that result from poorly managed irrigation can permanently destroy an area's agricultural potential. Though irrigation is perhaps the single most effective way to increase crop yields, it is a demanding technology that requires constant maintenance, sophisticated management, and the construction of expensive drainage systems in order to avoid severe environmental damage. Irrigation failures have a history that stretches back to the Mesopotamians, but they still claim large areas of prime agricultural land each year. As with other types of soil degradation, exact data do not exist, but worldwide, salinization is believed to be forcing as much land to be abandoned as is being newly irrigated. Technological sophistication is no protection: in the United States 20–25 percent of irrigated land is believed to be affected. And since the typical cost of irrigation systems is $1,000–2,000 per hectare (and sometimes much more) the costs of salinization are substantial, even on the scale of national budgets. (See Chapter 8, "Freshwater": Focus on: Irrigation; and Chapter 4, "Food and Agriculture": Irrigation.)

The precise sequence of events in soil degradation depends on the local environment, but the underlying cause is nearly always the same: greater human pressure on a fragile environment. Whether the principal local cause is the destruction of trees and shrubs in the search for fuelwood, the introduction of dryland agriculture to grow more food, poorly managed irrigation, or the overstocking of range to meet increased demand for meat and other livestock products, the challenge that must ultimately be met is to find ways to meet the needs of growing populations without destroying the resource base on which they depend. (See Chapter 5, "Forests and Rangelands": Table 5.13.)

## RELATING POPULATION AND RESOURCES

The growing world population poses huge challenges to sustainable management of the Earth's natural resources—its forests, soils, fisheries, and terrestrial species. In many regions these systems are already showing the signs of heavy human pressure. Yet by the year 2100 the planet's population will likely more than double. (See Chapter 2, "Population": Long-Range Projections.)

The relationship between population and the condition of natural resources is not a simple one. Capital investment can offset the effects of large numbers of additional people living on a fixed resource base. So can scientific discoveries and new technologies. The essentials for successful management under growing stress are knowledge, political will, and money. All of these are in short supply, especially in the developing world where 95 percent of the population growth in the next 70 years will occur. There, the grim reality of poverty makes calculations of what is possible of merely theoretical interest.

Even in low-income countries, labor devoted to soil conservation, afforestation, or irrigation can build the resource base to support a larger population. Sometimes fewer people are not better than more. One study has shown that the rural exodus from the Himalayan foothills, rather than lightening the load on a fragile environment, led to an unexpected *decline* in rural productivity, apparently because the women, children, and old people left behind were less able to maintain the area's intricate and vital soil terraces. In the vast majority of cases, however, the general rule holds: more people, especially more impoverished people, make the task of conserving already stressed resources all the more difficult. (See Chapter 2, "Population": Population and Resources.)

Among the few available measures of the balance between population and the resource base, "carrying capacity" is a potentially useful concept. But as yet it can not be accurately defined, much less measured. A study by the U.N. Food and Agriculture Organization (FAO), *Potential Population Supporting Capacities of Lands in the Developing World*, attempted to estimate the carrying capacities of 117 developing nations. The study relates soil types and climate factors to varying levels of agricultural investment in order to calculate the theoretical number of people a given country might be able to feed. Despite the sophistication and sheer magnitude of this study, a look at the number of assumptions that had to be made makes clear that the answers are no more than rough approximations. (See Chapter 4, "Food and Agriculture": Box 4.2.)

Another indicator linking resource condition to its degree of human exploitation is per capita yield. Here too, there are many pitfalls. Consider marine fisheries as an example. For two decades (1950–1970) the total world fish catch rose at a steady 7 percent per year, three times as fast as population growth, yielding a steady per capita increase. The catch dropped dramatically in 1971–72 with the crash of the Peruvian anchovy fishery. Growth resumed slowly, and through the 1970s grew at 1–2 percent annually—slightly less than the population growth rate—showing the beginning of what appeared to be a steady decline in per capita yield.

A closer look shows that the resource trend is much more complicated. For example, the fall in yield in the middle and late 1970s reflected not only the condition of the resource, but also the amount of human effort in fishing, which dropped following the bad years of the early 1970s. The tiny 0.2 percent increase between 1982 and 1983 was due in part to the negative effects of water temperature changes caused by the El Niño current in 1983. In fact, although final data are not yet available as this edition goes to press, preliminary indications are that the 1984 catch topped 80 million tons for the first time in history, with an increase over 1983 of as much as 8 percent, thereby breaking, at least for one year, the "trend" in per capita decline. (See Chapter 9, "Oceans and Coasts": The Marine Fisheries Harvest, and Table 9.1.)

Regional fisheries data make the picture all the more confusing. In the decade 1973–1983 some harvests increased as much as 1,000 percent, while others nearly disappeared. Some of these fisheries were just beginning to be exploited, others were recovering from—or *not* recovering from—earlier over-exploitation, and still others were being fished, at least for the moment, near the peak of their sustainable yield. (See Chapter 9, "Oceans and Coasts": Box 9.1; and Part IV, Table 10.2.)

While one cannot generalize from the fisheries to other resources, some of the implications of these data *are* more broadly applicable: beware global aggregates; trends may be treacherous; in any large scale system involving both biological phenomena and human activity, more forces are usually at work than any single indicator can account for; and biological resources *can* be over-exploited to the point of collapse, sometimes permanently.

While the relationship of population growth to resources is complex, some of the implications for governments are straightforward. More people means greater need for basic services—housing, education, health care and a job. Kenya's population is growing at 4.1 percent per year—the world's fastest rate. Between 1975–1980 Kenya devoted one-third of total government spending to education, health, rural water supply, and urban housing. If current fertility rates continue, the country will have to spend almost nine times as much between 2015–20 just to maintain current standards. Eleven million new jobs will have to be created by 2000, beyond those needed to cope with present unemployment and underemployment. Clearly, accommodating a rapidly expanding population demands rapid national economic growth, but much of this growth will not be sustainable, and thus not successful, unless it is grounded on sound resource management. (See Chapter 2, "Population": Box 2.2.)

Some of the challenges facing governments are breathtaking: by 2025, the projected working-age population in the developing countries alone will be larger than the world's present population. Finding jobs for these 5 billion people will be all the harder in a world where modern technology requires more literacy and education, and displaces more labor than ever before. (See Chapter 2, "Population": Age Distribution and the Labor Force.)

On the other hand, modern technology—both new methods of contraception and means of communication via television and satellite—offers the possibility of limiting fertility more rapidly than ever before. And because fertility rates affect future generations as well as the present one, they hold the key to the world's demographic future.

A young woman today who bears three children instead of the six her mother may have borne will have 27 great-grandchildren instead of 216 (assuming her children and grandchildren have the same fertility rate). Thus, filling the large unmet need for contraception is certainly one of the investments that stands to have the greatest impact on the future condition of the Earth's resources. (See Chapter 2, "Population": Stabilization, and Focus on: Fertility.)

## AFRICA

Africa is a special case. Nowhere else on the planet are resource trends so discouraging, the outlook so dire. Despite billions of dollars of external assistance, and thousands upon thousands of development projects and foreign experts, conditions have steadily worsened. Prominent among the reasons are rapid population growth, a difficult and often fragile environment, and resource mismanagement—sometimes due to lack of attention, and sometimes to policies and development strategies unsuited to local conditions.

The continent has the world's fastest population growth rate—3.01 percent per year, compared to about 1.67 percent for the world as a whole. Africa is adding people 10 times as fast as Europe, and more than three times as fast as the United States or the Soviet Union. At this rate, the number that must be fed, housed, educated, provided with health care, and employed will double in a scant 23 years. If current trends continue, Nigeria will eventually become the world's third most populous nation, with a population about equal to that of the entire continent today. (See Chapter 2, "Population": Population Growth by Region, Stabilization; and Part IV, Table 2.1.)

Why is growth so rapid? One answer was provided by the World Fertility Survey, conducted between 1974 and 1982. Women were asked how many children they would have "if they could choose exactly." The results revealed a substantial unmet need for contraception. In Latin America, for example, women would have two or three fewer children if they could choose. Only in sub-Saharan Africa did women seem to want as many children as they were having—a continent-wide average of 6.43 per woman. Again the question is: why? The answers are hidden in an intricate web of social, cultural and economic factors ranging from women's low status to the often vital labor provided by children. (See Chapter 2, "Population:" Unmet Need for Contraception, Figure 2.8, and Box 2.2.)

These numbing population statistics translate into about 1 million more mouths to feed every three weeks—the time it can take a planted seed to germinate. This burden must be borne on a continent in which more than 80 percent of the soils have fertility limitations, where 47 percent of the land is too dry for rain-fed agriculture, and where an area larger than the United States is ruled by the tsetse fly, whose bite spreads incurable trypanosomiasis (sleeping sickness) to people and livestock. It is not surprising, then, that in the 10 years following the 1974 World Food Conference, Africa was the only region of the developing world that did not meet the projected goal of a 2.6 percent annual increase in agricultural production. Worse, it combined less-than-expected production with higher-than-projected population growth. In only five of the 41 sub-Saharan nations did production growth exceed population growth. In many of the others, per capita food production fell by 20 percent or more, so that even before the current drought, one quarter of the total sub-Saharan population had become dependent on food imports. (See Chapter 4, "Food and Agriculture": Production and Consumption, Agriculture in Africa, Table 4.9; and Part IV, Table 5.3.)

Large parts of Africa are arid and semi-arid, areas where rainfall is sparse and, more important, highly variable. Average rainfall varies from year to year by a huge 30–40 percent, so that "normal" precipitation means something quite different from what it means in the temperate zones. What *is* normal are multiyear, recurrent droughts—of which there have already been three in this century. (See Chapter 8, "Freshwater": Variability of Rainfall, Figure 8.5, and Box 8.1.)

The traditional African nomadic way of life was a successful solution to this environment. Though nomadism provided only a subsistence-level existence, and was disparaged by foreign experts, modern science is just beginning to understand how well-suited the system is to its environment. Recent studies are finding that the productivity of Sahelian animal husbandry (measured in animal protein per unit area) equals or exceeds that of ranches in comparable rainfall regions of the United States and Australia. This realization comes, however, after two decades of foreign assistance and domestic policies aimed at replacing pastoralism with settled agriculture, largely through the digging of wells. Today the worst rangeland conditions in the Sahel are found near year-round water supplies and where pastoral and agricultural land uses coexist. Large homogeneous herds of cattle were another misguided innovation. The traditional smaller mixed herds made much better use of the scarce resources, with camels, sheep and goats eating vegetation cattle do not touch. (See Chapter 5, "Forests and Rangelands": Condition of Rangelands and Development Assistance and Range Management, Table 5.13, and Box 5.1.)

Africa's agricultural production can certainly be boosted, but for various reasons many of the modern approaches are of limited applicability. For example, Africa, of all the continents, has the lowest potential for irrigation. Except in South Africa and along the Nile River, unfavorable topography, low groundwater reserves, insufficient trained managers, and inadequate funds severely limit its prospects. Only Oceania, among the world's regions, has as low a percentage of irrigated cropland. (See "Food and Agriculture": Irrigation, Table 4.6; and Part IV, Table 5.2.)

Closely tied to its agricultural problems is Africa's fuelwood crisis. Many African countries depend on fuelwood and other forms of biomass for more than 90 percent of their energy. Even in oil-rich Nigeria, fuelwood is the primary fuel. Today nearly 40 percent of all Africans must cope with a deficit or an acute scarcity of fuelwood. By 2000, the number is projected to have more than doubled and the proportion to reach 60 percent. In rural areas the fuelwood shortage means more erosion, lower soil fertility, less forage for livestock, and growing human suffering. The environmental impacts are felt in urban areas as well. As fuelwood and the charcoal made from it are trucked in to supply urban residents, an expanding "ring of desolation" surrounds the cities. (See Chapter 7, "Energy": Biomass Fuels, Focus on: Fuelwood Scarcity, and Table 7.8.)

Though the immediate outlook is not promising, Africa's resource problems should not prove insurmountable. However governments' policies, and, where policies are favorable, governments' weak capacities to act, remain major hurdles. In 1985, Julius Nyerere, President of Tanzania, succinctly described where things now stand for many governments: "Until the last few years, Africa regarded environmental concern as an American and European matter. Indeed there was a tendency to believe that talk of the environment was part of a conspiracy to prevent modern development on our continent! Now we have reached the stage of recognizing that environmental concern and development have to be linked together if the latter is to be real and permanent. The question is how to do this." For a great many of these problems, the "how" is still unclear. Basic data are unavailable, properly focused research is sparse, government institutions are weak, and international assistance, though well-intentioned, is often misdirected. Still, there is reason for hope. Governments and a growing number of citizens' groups are beginning to understand and to act upon the linkages between Africa's unique environment and its development prospects. (See Chapter 11, "Policies and Institutions": Assessment, Management: The Capacity to Act, and The Larger Context.)

# 2. Population

Because population, availability of resources, quality of the environment and prospects for economic growth are inextricably linked, understanding the dynamics of world population growth is the logical starting point for a study of the resources that sustain life on Earth.

## CONDITIONS AND TRENDS

### POPULATION GROWTH TO THE PRESENT

The growth of the world population may be the greatest of all the changes of the 20th Century. Although the rate of growth has fluctuated, unprecedented population growth has been an enduring characteristic throughout wars, famines, economic boom and bust, technological advances, and dramatic shifts in the global power structure.

At the beginning of the century there were about 1.6 billion people in the world. Initially the growth rates were low, averaging about 0.8 percent per year for the first half of the century (1). By mid-century there were 2.5 billion people on Earth, and by 1985 this figure had nearly doubled to 4.8 billion (2).

To put that figure into perspective, it helps to look back at the growth of human numbers since mankind's appearance on earth. It took the human family millions of years—until around 1800—to reach the one billion mark. (See Figure 2.1.) It only took 130 more years to reach the second billion, in about 1930. The third billion was added by about 1960, and the fourth in 1975 (3).

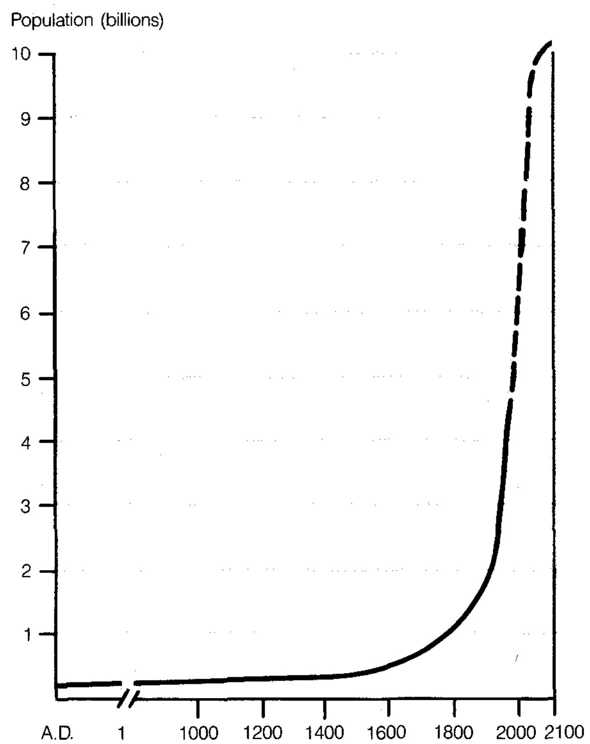
Early in the second half of the century the population growth rate accelerated until the year 1970 when it reached what might have been an all-time historical high of 2.06 percent per year. Stated differently, the rate of growth of the world population increased from about 2 percent *per thousand years* in the prehistoric past, to about 2 percent *per year* in 1965–70.

The early 1970s marked an historic turning point. For the first time in human history, the growth rate began to decline, and this trend has continued. However, because of the immense momentum built up in the past, the continuing decline in mortality rates, and the high absolute numbers involved, more people are still being added to the Earth's total each year.

During 1985, when the global population was estimated at about 4.8 billion, approximately 80 million people were added to the human race. This is equivalent to the total of the current populations of New York City, Moscow, London, Beijing (Peking), Mexico City, and Rio de Janeiro. If a decline had not begun, the annual increment of global population would be even higher. As it is, the annual increment for the period 1995–2000 is projected to be about 90 million (4).

What is "rapid" population growth? The term generally refers to annual increases of about 2 percent or more (5), but there is no absolute threshold. (A population growing

**Figure 2.1 Past and Projected World Population, A.D. 1–2100**




**Source:** World Bank, 1984, Reference 18, p. 3.

at 2 percent a year will double in 35 years; at 3 percent in 23 years, and at 4 percent a year it will double in 17.5 years.) In 1985 the world's highest rate of population growth—4.1 percent—occurred in Kenya. The growth rates of India and Indonesia, which are more than 2 percent, would be classed as "rapid," while that of China (1.17 percent, a doubling time of 60 years) would not.

Since the global population numbers in the billions, even a small rate of increase or "compound interest rate" can produce considerable yearly increments. Just as some countries' national debts assume immense proportions because of periodically compiled interest, so too do some countries' populations increase enormously. Working with ten-digit figures, even a small difference in the rate of growth can be very significant.

## Growth by Region

Growth occurs at very different rates in different parts of the world. (See Figure 2.2.) The developed world grew from 0.8 billion in 1950 to 1.2 billion in 1985. In the same period, the population of the Third World increased from 1.7 billion to 3.7 billion (6,7).

Differences between regions were significant. The greatest absolute decline in growth rate occurred in East Asia, and most of that was accounted for by China. At the beginning of the period, Latin America was the fastest-growing region, while by 1985 Africa was the leader. The regional shares of the global population in 1950 and 1985 can be seen in Table 2.1. Since 1950 there has been some shifting of the rank order, with Africa overtaking Europe to become the world's third most-populous region.

In terms of sheer numbers, China and India dwarfed the others on the list of the world's 12 most populous countries: China, 1.063 billion; India, 761 million; the Soviet Union, 276 million; the United States, 238 million; Indonesia, 165 million; Brazil, 136 million; Japan, 130 million; Pakistan, 102 million; Bangladesh, 101 million; Nigeria, 95 million; Mexico, 79 million; and the Federal Republic of Germany, 61 million.

## POPULATION AND RESOURCES

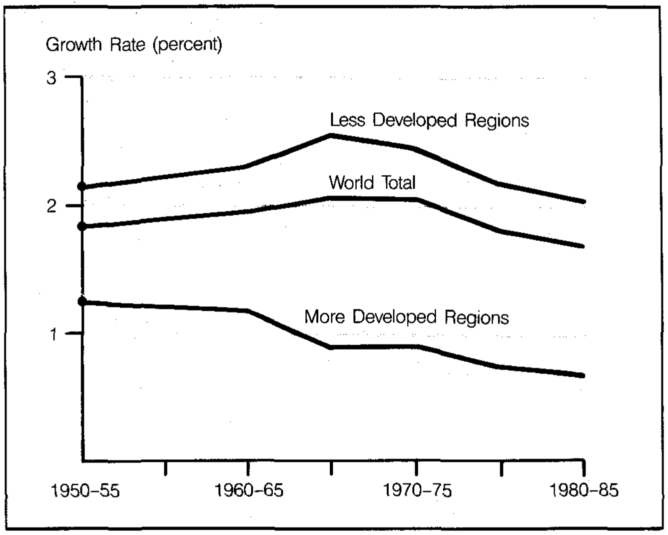
Population growth subjects natural resources and the environment to increased pressure, but the relationship is not a simple one. Where land and other resources are already under stress—in absolute terms or because of poor management—the impact of additional people can be direct and strongly negative. Where resources are more ample, or where economic investment buffers the impact of more people, the connection becomes much more complicated.

One commonly used indicator of the link between population and resources is population density. However, the number of people per square kilometer, though easily measured, is not very revealing. Clearly, simple Malthusian equations are not equally at work in Singapore with a 1975 population density of 53 people per hectare and Senegal with less than one person per hectare, when life expectancy at birth in 1980 was 72 years in Singapore, and only 44 years in Senegal. Nor does the contrast between the 1985 population densities of the Netherlands, 335 per square kilometer, and Norway, 13 per square kilometer, reveal much about the two countries. Much of the land in the Netherlands was dredged out of the sea, and nearly every square inch is put to use, while most of Norway's land is taken up by largely uninhabited mountains.

The concept of carrying capacity is another approach used to link population with the natural resource base (8). Though much used by biologists and ecologists, the term has not yet been well defined. Since the adoption of a recommendation at the 1974 World Population Conference in Bucharest, a number of studies have been launched to understand "the complex relations among the problems of population, resources, environment, and development, and to promote a unified analytical approach to the study of these interrelationships" (9). But progress toward this lofty goal is still limited.

The United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and the Biosphere (MAB) Program has concentrated on the study of these relationships in island ecosystems, particularly Fiji and Barbados, where methodological problems can be more easily solved. Other work is currently underway in the

**Figure 2.2 Average Annual Population Growth Rates in More Developed and Less Developed Regions, 1950–85**




**Note:** More developed regions include Europe, North America, Australia, Japan, New Zealand, and USSR. Less developed regions include Africa, Asia, Latin America, and Oceania.
**Source:** Department of International Economic and Social Affairs, 1985, Reference 2.

Himalayan Mountains where the steep slopes accentuate the relationships among population, soil erosion, and downstream flooding. These studies shed light on simplistic notions about the harmful effect of dense populations on natural systems. For example, the movement toward cities from the Himalayan foothills led to an unexpected decline in rural productivity as those left behind (the old, the women, and the young) were less able to maintain vital soil conservation terraces (10).

Most such studies have as their purpose a better understanding of these relationships to aid improved national planning (11). The most ambitious such endeavor was undertaken following the first "Sahelian drought," the massive food shortages in West Africa in the early 1970s, by the U.N. Food and Agriculture Organization (FAO), the U.N. Fund for Population Activities (UNFPA), and the International Institute for Applied Systems Analysis (IIASA). The study investigated the degree to which natural productivity (chiefly determined by climate, latitude, soil type, and similar parameters) can be augmented by mechanization, irrigation, fertilizers, pesticides, and the like, to reach production levels sufficient to maintain present and projected populations. (See Chapter 4, "Food and Agriculture," Box 4.2, "Land, Food, and People.")

A third approach to the relationship of population to natural resources looks at per capita production as the principal indicator. Some studies show that world grain production per capita peaked in the 1970s, as did fish and beef production; and that while, in the case of grain, increased yields could still be obtained through increased use of fertilizer, there was a declining response per unit of input (12).

None of these approaches, however, yet provides an analytically sound method of studying these vast and complex relationships. More research and new ideas are badly needed.

**Table 2.1 Share of World Population by Region, 1950 and 1985**
*(population in millions)*

| Region | 1950 (millions) | Percent of World Total | 1985 (millions) | Percent of World Total |
|---|---|---|---|---|
| Africa | 222 | 8.9 | 553 | 11.4 |
| Latin America | 165 | 6.6 | 406 | 8.4 |
| North America | 166 | 6.6 | 263 | 5.4 |
| East Asia | 571 | 22.8 | 1,252 | 25.9 |
| South Asia | 695 | 27.8 | 1,572 | 32.5 |
| Europe | 392 | 15.7 | 492 | 10.2 |
| Oceania | 113 | 4.5 | 25 | 0.5 |
| USSR | 180 | 7.1 | 278 | 5.7 |

**Source:** Department of International Economic and Social Affairs, 1985, Reference 2.

## PROJECTIONS OF THE FUTURE

Future world population is also a subject of intense research and debate (13,14). Its main components are past and present fertility and mortality rates and international migration figures. For the near term, population projections are relatively secure, because the next generation and the parents of the generation after next have already been born.

However, projections are not forecasts. They are no more than educated extrapolations of current trends, and even near-term projections rest on numerous assumptions. Moreover, current trends often change rapidly. Even though equipped with the world's best census data, for example, demographers misjudged the size and duration of the postwar baby boom in the United States.

The United Nations Population Division projects country-by-country populations to the year 2025, and regional projections to the year 2100. The World Bank, on the other hand, provides country-by-country projections to the year 2155 (15). The projections from these two United Nations organizations, together with those of the United States Census Bureau, constitute the universe of widely accepted and regularly published projections. For most countries, the differences in the projections over the near term are very slight.

Most of the population figures used in this chapter are taken from the United Nations projections to 2025 published in 1985 (16), and from the United Nations long-range projections published in 1981 (17). These projections are based on adjusted data from the most recent national censuses.

To illustrate the uncertainties, consider the United Nations' 1985 projections. Among the assumptions on which they rest are that unpredictable catastrophes such as wars, famines, and epidemics will not occur. Steady socio-economic growth and a steadily declining fertility rate were assumed for the developing countries. Life expectancy was assumed to grow by 2.5 years during every five-year period—as it has in many developing countries during recent decades—up to 82.5 years for women and 75 years for men. Adjustments were factored in for developed countries where life expectancy is already high, and for some developing countries (for example, sub-Saharan Africa) where conditions are not conducive to lengthened lifespan.

Analysts further assumed that existing or anticipated government family-planning programs would accelerate fertility decline. Where a decline in fertility was already evident, it was expected to begin slowly, accelerate, and then slow down. Principally because of incomplete knowledge and past abrupt changes, international migration was assumed to cease entirely, except where there is strong evidence to the contrary (for example, between Mexico and the United States). Analysts even ventured to consider "trends and anticipated changes in socio-economic and cultural values of the society." And finally, four variants—high, medium, low, and constant—were chosen and "crossed" among the assumed levels of fertility, mortality, and migration, to give a wide range of possible futures. Clearly, even relatively short projections are subject to many surprises, especially for the developing countries where very large populations, high birth and death rates, and shifting government policies combine to make the demographic future very difficult to foresee.

## LONG-RANGE PROJECTIONS

Figure 2.3 provides a graphic illustration of the projected future of the human population to the year 2150, based on the United Nations long-range medium variant projections. By the year 2100, the Earth's population would have more than doubled, with 95 percent of the increase between the years 1980 and 2050 taking place in the Third World. While the population of the developed regions would have grown to 1.4 billion by 2100, that of the developing regions would swell to 8.8 billion.

Considerable shifts would occur among the major regions of the world (see Figure 2.4). Africa would continue its current surge of growth to emerge as the second most populous region of the world. South Asia, where about 1.5 billion people lived in 1980, would be home in 2100 to more than double that number. East Asia, where China exerts the dominant demographic influence, is projected to level off in about the year 2030. The population of Latin America is projected to continue growing, but at decreasing rates. Europe, North America, and the Soviet Union would follow a low-growth pattern throughout the period. Although the cumulative increase in these three more developed regions would be relatively small, it translates into an additional 270 million people, or nearly the present population of the Soviet Union.

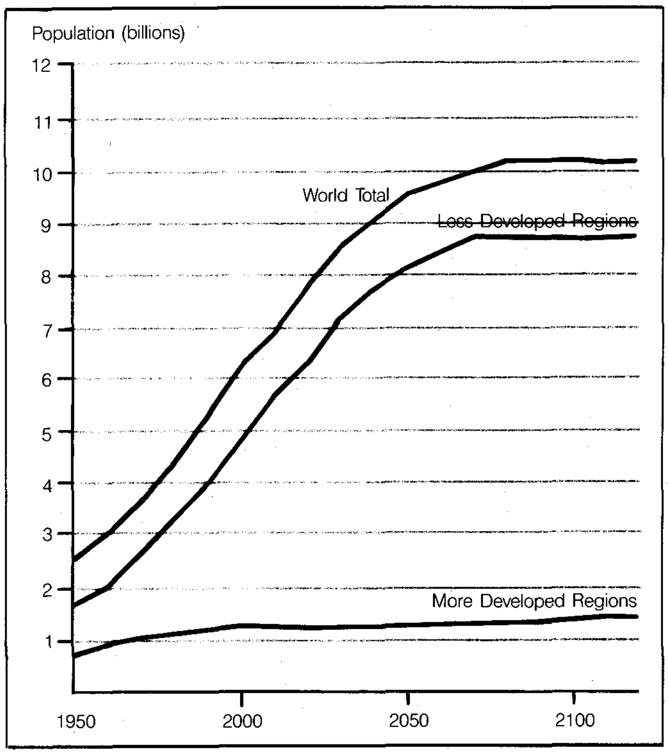
### Stabilization

Long-term extrapolations that assume rising life expectancy to an eventual maximum and declining fertility that eventually reaches replacement level, project a world population that eventually stabilizes. If fertility drops below replacement level and does not climb back up, as it has to date in several parts of the developed world, eventual world population would slowly decline. The United Nations and the World Bank projections for the dates when net reproduction rates reach 1.0 are shown in Table 2.2.

As with shorter projections, these estimates depend on many underlying assumptions: the more extended the projection, the more tenuous the connection to reality. According to the United Nations medium variant projections, if the net reproduction rate of 1.0 (replacement level fertility) is reached by the year 2035, the global population would stabilize by the year 2100 at 10.2 billion. The World Bank's estimated hypothetical stationary population is 11.2 billion. Although U.N. forecasters consider their medium variant projection to be the most plausible, four other variants were prepared to provide a reasonable range. The projections for the year 2100 vary from a low of 7.2 billion to a high of 14.9 billion.

The most illuminating feature of such estimates is the impact of what happens now and in the near future, especially to fertility. Fertility declines have more influence than do drops in mortality because high fertility means many more people added over generations. A baby girl who grows up to have 3 children instead of 6, will have 27 great-grandchildren rather than 216 (18). If unexpected changes in fertility rates delay or advance the projected stabilization date, the consequences for eventual population levels are immense. A 20-year delay in a replacement level date of 2025 means an eventual popula-

**Figure 2.3 Population Size for More Developed Regions, Less Developed Regions, and World Total, 1950–2120**




**Note:** More developed regions include Europe, North America, Australia, Japan, New Zealand, and USSR. Less developed regions include Africa, Asia, Latin America, and Oceania.

**Sources:**
1. Department of International Economic and Social Affairs, *World Population Prospects as Assessed in 1980, Population Studies No. 78* (United Nations, New York, 1980), p. 12.
2. Department of International Economic and Social Affairs, *Long-Range Population Projections of the World and Major Regions, 2025–2150, Five Variants, as Assessed in 1980, 1981* (United Nations, New York, 1981).

tion 2.8 billion larger. A 20-year advance means 2.2 billion people less. The difference over this short 40-year span is more than the present total world population (19).

The World Bank's country-by-country projections to the year 2100, however speculative, provide tantalizing glimpses of future possibilities. Perhaps the most surprising projection is for the west African country of Nigeria. Few are aware that Nigeria may eventually become the world's third largest country. According to these projections, by the time Nigeria's fast-growing population finally stabilizes, probably after the year 2100, it may reach half a billion. Only China and India are projected to have larger populations by the time they stabilize; 1.5 billion for China and 1.7 billion for India.

## MORTALITY

### Life Expectancy

Life expectancy, the number of years a typical individual can expect to live, given current levels of mortality, has increased greatly since 1950, and is expected to improve further in the future.

On a global level, life expectancy increased from 45.8 years in 1950–55 to 58.9 years in 1980–85, and according to the U.N. projections is expected to reach 70 by the year 2025. Present life expectancy in the more developed countries averaged 73 in 1980–85, and in the less developed regions it was 56.6; the estimates for 2025 are 77.2 and 68.9, respectively.

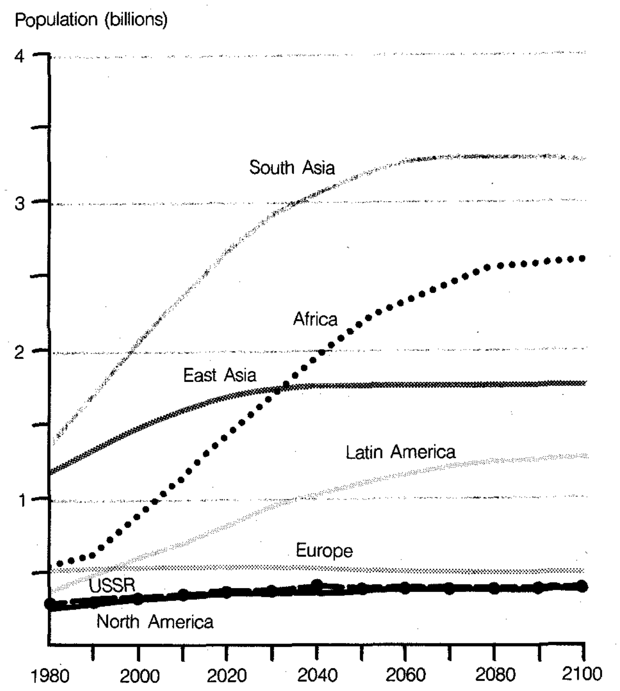
In countries where life expectancy is already high and may be bumping up against some biologically determined ceiling, the rate of improvement has slowed. For example, in Iceland, which had the world's highest life expectancy of 77.6 years in 1980–85, only a slight increase, to 78.2 years, is projected by the period 2020–25. In Sudan, an increase of 28.8 years is projected during the same time span.

Although in most countries women have a longer life expectancy than men, the opposite is true in some countries of South Asia. Countries where female life expectancy is lower include Afghanistan, Bangladesh, India, the Islamic Republic of Iran, Nepal, and Pakistan. The relatively low status and high fertility of women in these countries may be contributing factors (20).

### Economic Well-Being

In general, mortality and national income are inversely related, but there are many variations and some exceptions to this rule. The countries of South Asia and sub-Saharan Africa tend to have the lowest incomes and the highest mortality rates, while the wealthier countries of Latin America and East Asia have lower mortality. However, as Figure 2.5 shows, virtually all developing countries showed longer life expectancy over the decade 1972–82, even where per capita income did not grow significantly. And some countries—China, Sri Lanka, and Costa Rica, for example—do far better than the average at their income level. The key factors are access to health care, a national emphasis on the provision of this and other basic human services, and a relatively egalitarian economic structure (21).

**Figure 2.4 Projected Total Population of Major Regions, 1980–2100, as Assessed in 1980**




**Source:** United Nations Secretariat, *Population Bulletin of the United Nations*, No. 14 (United Nations, New York, 1983), p. 24.

Large differences in mortality exist not only between rich and poor countries, but also between different social strata within countries (22). In France, the probability of death for males aged 55–65 during the period 1966–81 was three times higher for unskilled workers than for men working in senior management and in the professions. In England and Wales, there are significant differences in life expectancy between socio-economic groups and social classes. In the United States, infant mortality rates have long been significantly higher for the nonwhite population.

### Infant Mortality Rates

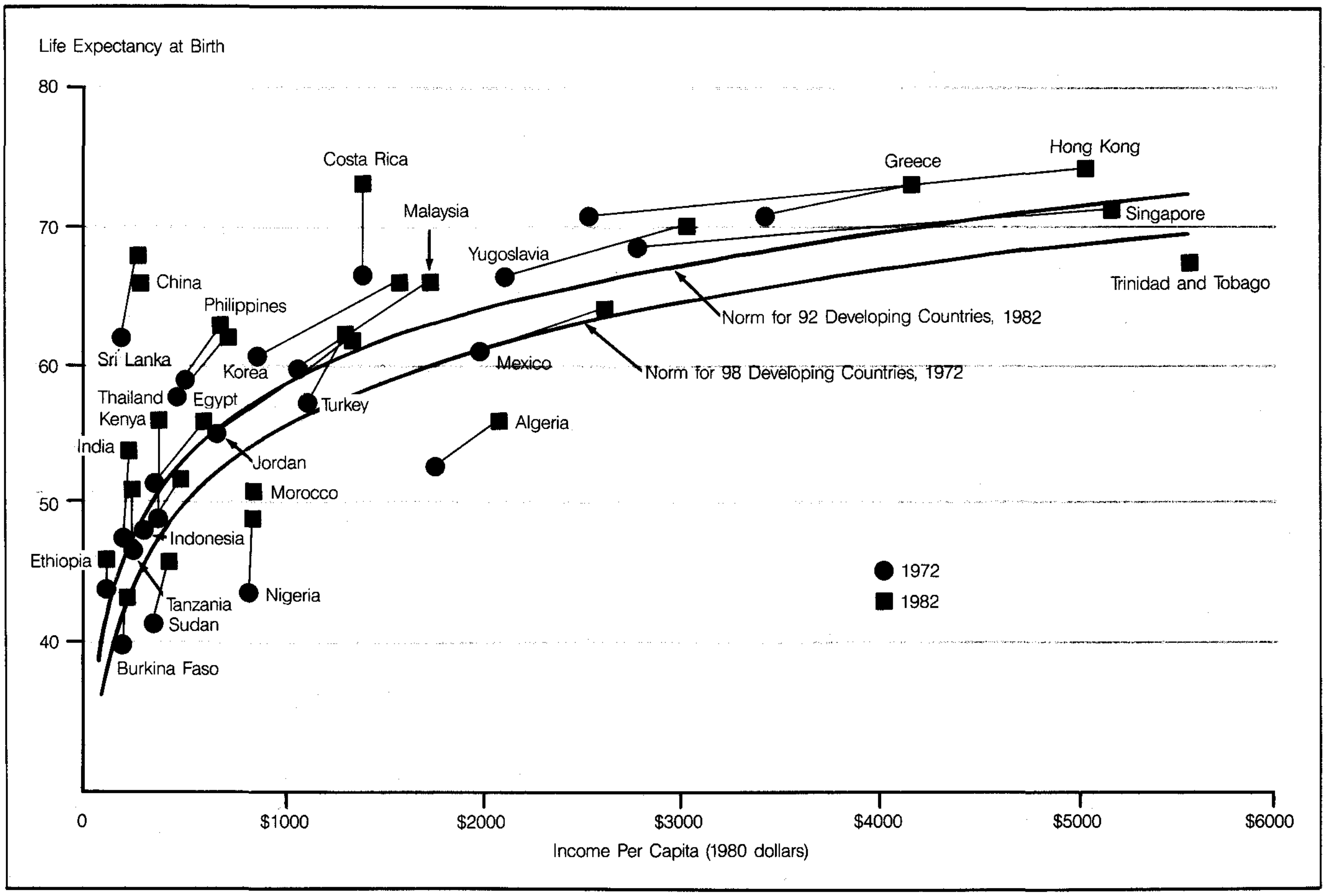
Much of the improvement in mortality rates can be attributed to the fact that more infants are surviving the

**Table 2.2 Year in Which Net Reproduction Rate (NRR) Reaches 1**

| United Nations Projection | | World Bank Projection | |
|---|---|---|---|
| East Asia | 1990 | USSR | 2000 |
| North America | 1995 | North America | 2010 |
| Europe | 2020 | Europe | 2010 |
| South Asia | 2020 | Latin America | 2030 |
| USSR | 2030 | Oceania | 2035 |
| Oceania | 2035 | Asia | 2045 |
| Latin America | 2040 | Africa | 2045 |
| Africa | 2045 | | |

**Source:** United Nations Secretariat, "Long-Range Global Projections, as Assessed in 1980," *Population Bulletin of the United Nations*, No. 14 (1982) p. 20.

**Figure 2.5 Life Expectancy in Relation to Income in Developing Countries, 1972 and 1982**




**Source:** World Bank, 1984, Reference 18.

precarious first year of life. Still, conditions in some countries are so difficult that more than one in ten babies dies in its first twelve months. (See Figure 2.6.) Recently, the rate of improvement in infant and child mortality has slowed significantly. (See "Recent Developments," below.)

In general, infant mortality rates serve as indicators of a country's socio-economic condition. Among the factors influencing infant and child mortality are: the mother's age (younger and older mothers are more liable to lose their babies), length of interval between births (longer intervals are healthier), and the education of the parents (lower infant mortality rates are associated with educated parents). Also, first babies born to very young mothers and high-order births (such as the sixth or seventh child) are more vulnerable (23).

## THE DEMOGRAPHIC TRANSITION

The developed countries have already made the demographic transition from a high mortality status to a low mortality-low fertility condition, while the developing countries are in the process of doing so. The demographic history of a country like Sweden (See Box 2.1) illustrates the differences between the typical road traveled in the 18th and 19th Centuries, and that facing developing countries today. In most of today's developed countries, mortality declined slowly, principally because of improved living standards: this was still the period before medical achievements had made much of an impact. During this period fertility rates were also low. As population grew, emigration relieved the pressure. In one 90-year period, 45 percent of the increase in the population of the British Isles emigrated (24).

For today's developing countries, the situation is quite different. A transition that took more than a hundred years in a country like Sweden is happening in the space of a few decades in a country like Sudan. Mortality drops rapidly, principally in response to immunization, antibiotics, control of malaria, and other forces of modern medicine. As Figure 2.7 illustrates, fertility rates are far higher than those faced earlier by the developed countries. Emigration provides few opportunities. (See Table 2.3.) Moreover, since the initial population base is usually quite large, annual increments can be very substantial. Modern society requires more literacy and education while technology displaces more labor than before—both forces that increase the demands on government services.

On the other hand, modern communication and methods of contraception make it possible to greatly speed the control of fertility.

## Age Distribution and the Labor Force

The world's population is getting older. The median age has increased slightly from 22.9 years in 1950 to 23.3 in 1985. By the year 2025, the median age will exceed 30 (25). The trend from 1980 through 2100 shows a relatively rapid increase in the portion of the population aged 60 and over. In the developing countries, their numbers are projected to increase from 214 million in 1950 to more than a billion by 2025 (26).

The 0–14 age group, on the other hand, is projected to experience a relative decline, although the absolute increase in the number of youth will challenge the educational institutions of tomorrow. In the less developed countries, an estimated 500 million additional people are expected to have entered the labor market by the turn of the century (27). By the year 2025, the working age population in the developing countries alone will be larger than the world's current population (28).

Providing jobs for this vast new work force will demand far-reaching changes in most governments' investment strategies, systems of land tenure, and tax and pricing policies (29).

## FOCUS ON: FERTILITY

Explaining fertility decline has proved to be even more difficult than recording it. What are the determinants of fertility change? What factors are at work to determine the number of children people have?

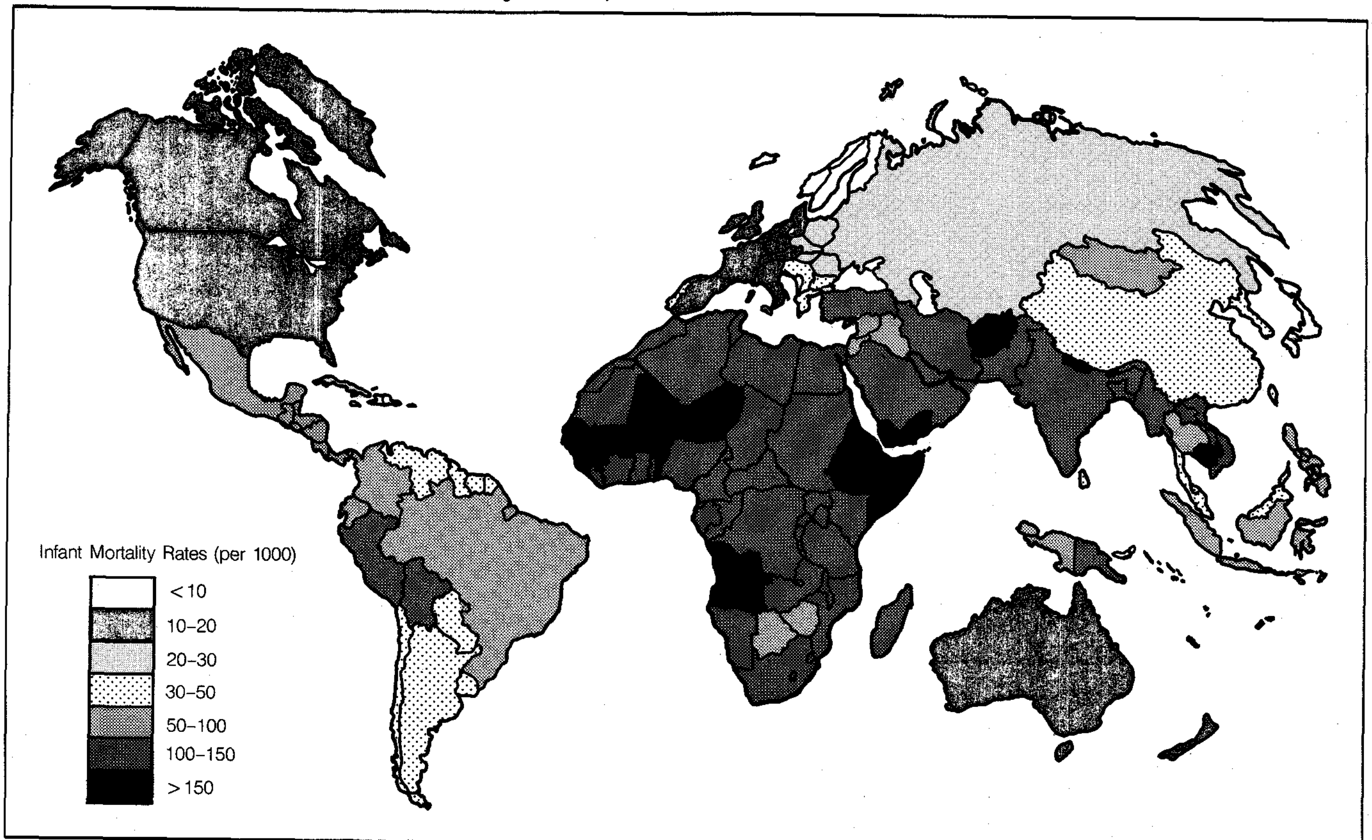
In the world as a whole, the total fertility rate (TFR), the average number of children a woman bears in the course of her child-bearing years, declined from 4.99 in 1950–55 to 3.90 in 1975–80. The TFR is projected to decline to 2.32 by 2020–25 (30).

By region, East Asia led the decline in fertility, dropping from 2.44 in 1950–55 to 1.9 in 1975–80, with a projected continued decrease to 1.13 in 2020–25. Latin America and South Asia have also experienced noteworthy fertility declines. In Africa, on the other hand, there was little change in the fertility rate between the years 1950 and 1980. Yet the United Nations projects a rapid decline in the future.

North America and Europe have seen steep fertility declines, but rates are projected to eventually pick up again, slightly, to reach replacement levels. The Soviet Union is projected to continue its slow decline, eventually reaching a level just above that of North America.

During the period of the World Fertility Survey, 1974 to 1982, fertility was highest in the Middle East and sub-Saharan Africa, with an average of seven children per

**Figure 2.6 Estimated Infant Mortality Rates, 1975–80**




**Source:** *Department of International Economic and Social Affairs, 1985, Reference 1, p. 24.*

## Box 2.1 The Swedish Example

Sweden is unique in having an unbroken series of poulation statistics from the year 1749. These statistics tell the story of how Sweden gradually transformed itself from a poor, developing country with high birth and death rates to a prosperous country with birth and death rates that are among the lowest in the world (1).

### FROM 1750 TO 1850

Around the year 1750, Sweden was largely an agrarian society with a rigid, hierarchical class system. The average life expectancy for men was 34.2 years; for women it was 37.6 (2). (In 1980–85 only a few countries had life expectancies below 40 years; they included Sierra Leone, Gambia, and Afghanistan (3).) In the mid-1700s, the Swedish population of about 1.7 million was more or less defenseless against infectious diseases such as smallpox and spotted fever. Dysentery, measles, and whooping cough took heavy tolls. Periods of famine left the population weakened and susceptible to diseases. Some efforts were made to provide organized maternity care and to establish famine relief, but conditions remained difficult. Nevertheless, by the year 1850, the life expectancy for Swedes had increased to 43.5 years for women and 39.4 for men. Infant mortality rates improved steadily. From 1750 to 1850, the population doubled (4).

### FROM 1850 TO 1930

Because of a series of advances, including hospital care; vaccination against smallpox; antiseptics; and improved hygiene, sanitation, water supply, and sewage systems, mortality rates fell and the population grew until, by 1900, it was considered a national problem.

A wave of emigration then swept the country, as it had other parts of Europe, and about one out of every five Swedes moved out. Birth rates continued to decrease, and mortality rates decreased even more. The population continued to grow (5).

### FROM 1930 ON

At the beginning of the 20th century, Sweden was still a poor country with many social and economic problems. By 1930, housing remained overcrowded, and sanitary and hygienic conditions were poor. Wide disparities existed between social classes, as seen in the infant mortality rates, which ranged from 49 deaths per 1,000 births in low-income families to 14 in high-income groups.

On the positive side, the beginnings of prosperity were seen: an early law had virtually eliminated illiteracy, women enjoyed a relatively high status and joined the labor force in increasing numbers in the 1920s and 1930s, and child labor began to disappear. The cost of raising a child at the time was equivalent to a third of the average income. The birth rate continued to fall.

Traditionally, social security against illness, old age, unemployment, and accidents was supplied by the large, three-generational family, the neighborhood, the parish, and the church. By the 1930s, the nuclear urban family had emerged and the old support net was no longer there. At that time some forms of government social security were introduced, along with a national health insurance scheme, and employer insurance against occupational accidents or diseases.

When Alva and Gunnar Myrdal published their book *Crisis in the Population Issue* in 1934, the basis for the modern Swedish view of population problems was established. "Revolutionary" ideas that were intended to stimulate the birth rate were introduced including maternity welfare, increased maternity benefits, tax incentives, housing allowances, nursery schools, children's health services, free school meals, cheaper educational facilities, and massive information/education campaigns on housing, nutrition, and health. Particularly important was the concept of "voluntary parenthood," meaning that only wanted children need be born.

During the 1940s, more reforms were introduced, such as day care nurseries and kindergartens, loans for newly-married couples, and fewer restrictions on abortions. In 1956, sex education became compulsory (6).

### SWEDEN NOW

The population of Sweden grew from 6.4 million in 1940 to 8.3 million in 1985. Immigration from abroad accounted for most of the increase. During decades of prosperity, the total fertility rate fell from 2.22 in 1950–55 to 1.55 in 1980–85, indicating that the average Swedish woman had 1.55 children, too few to allow the replacement of the current generation of Swedes (7).

In 1982, an official survey was authorized to determine why so few children were born (8). The results of the survey indicated:

- More women were obtaining higher levels of education than in the past, thus postponing their childbearing years.
- The more education a woman had, the fewer children she was likely to have.
- More women were in the labor force, and those with higher-status jobs had, as a rule, fewer children than those with lower-status jobs.
- Nearly all women considered having children as one of the meaningful things in life.
- More young Swedish couples lived together without being married, and people were not as likely to have children outside of marriage.
- The use of effective methods of contraception was widespread.
- Finding day-care was a problem for many working women.
- By far the greatest burden of housework, cooking, and shopping was carried by women, including those working full-time who had children. In fact, after women had children they shouldered even more household duties.

Sweden's growth rate, 0.01 in 1980–85, is projected to be -0.14 in the period 1985-90. Life expectancy, 75.8 in 1980–85, is one of the highest in the world. The infant mortality rate is one of the lowest in the world, at seven infant deaths per 1,000 births (9).

This is the pattern that has been repeated, with many variations, throughout the developed world. The road from high to low mortality in the developing countries will be a much shorter, and rockier, one.

### References and Notes

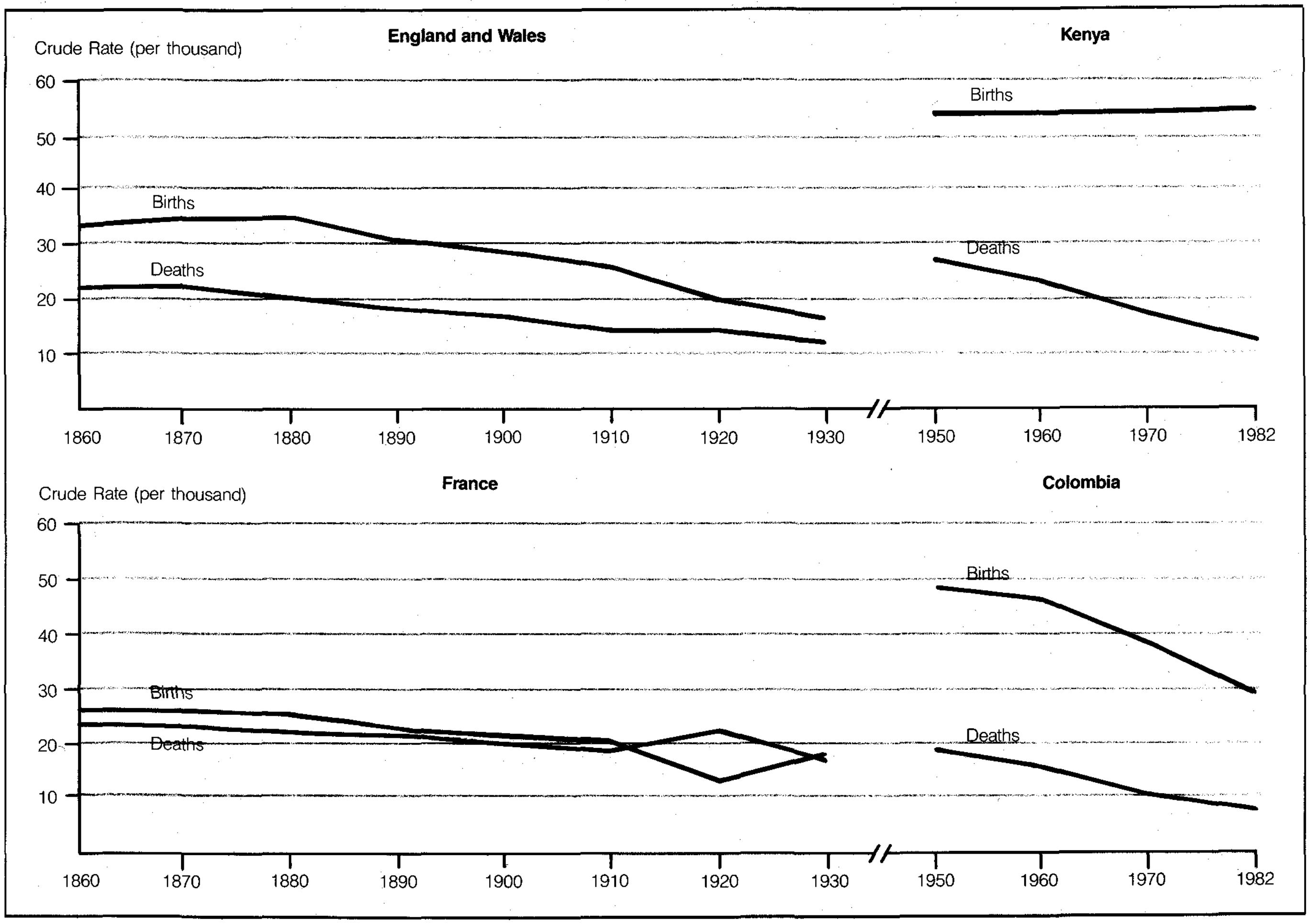

1. Royal Ministry of Foreign Affairs, *The Biography of a People* (Royal Ministry of Foreign Affairs, Stockholm, 1974).
2. *Ibid.*
3. Department of International Economic and Social Affairs, *World Population Prospects, Estimates and Projections as Assessed in 1982*, Population Studies No. 86 (United Nations, New York, 1985), Annexes.
4. Statistika Centralbyran Prognosinstitutet, *Kvinnor och barn, Intervjuer med kvinnor om familj och arbete, Information i prognosfragor 1982:4* (Statistiska Centralbyran Prognosinstitutet, Stockholm, 1952); and International Statistical Institute, *World Fertility Survey in Sweden, 1981: A Summary of Findings* (International Statistical Institute, Voorburg, the Netherlands, April 1984).
5. *Op. cit.* 1.
6. *Op. cit.* 1.
7. *Op. cit.* 3.
8. *Op. cit.* 4.
9. *Op. cit.* 3.


woman. (See Box 2.2.) The average number of children per woman was six in North Africa and 4.5 in Asia and the developing countries of Central and South America (31).

Some of the variables suggested as responsible for fertility decline include (32):

- The spread of family planning programs and availability of contraceptives
- Decreases in childrens' contribution to the family labor force and family income
- Less need for children as insurance against old age or accidents
- Higher cost of raising and educating children
- More education for women
- Urbanization

**Figure 2.7** **The Demographic Transition in Developed and Developing Countries**




**Source:** World Bank, 1984, Reference 18, p. 59.

- Increase in the marriage age of women

On the other side of the equation are changes that enhance fertility and that often accompany "modernization". These include a reduction in breastfeeding, a departure from traditional customs such as long periods of sexual abstinence following childbearing, and relaxation of the custom forbidding widows to remarry.

The state of fertility around the world was assessed by the World Fertility Survey (WFS), the largest social science survey ever undertaken. The WFS covered 42 developing and 20 developed countries between the years 1974–82. Over 300,000 married women between the ages of 15 and 49 were interviewed, providing internationally comparable data on fertility levels and trends, and women's aspirations concerning the size of their families. Prior to the WFS, good-quality, comparable data were hard to come by. Undoubtedly, the WFS's most important contribution was the demonstration that although economic development and family planning programs can each independently promote fertility decline, the effect is greatest and most rapid when the two occur together.

**Table 2.3** **Percentage of Population Increase that Has Permanently Emigrated[a]**

| Period | Europe | Asia[b] | Africa | Latin America[b] |
|---|---|---|---|---|
| 1851-80 | 11.7 | 0.4 | 0.01 | 0.3 |
| 1881-1910 | 19.5 | 0.3 | 0.04 | 0.9 |
| 1911-40 | 14.4 | 0.1 | 0.03 | 1.8 |
| 1940-60 | 2.7[c] | 0.1 | 0.01 | 1.0 |
| 1960-70 | 5.2 | 0.2 | 0.10 | 1.9 |
| 1970-80 | 4.0 | 0.5 | 0.30 | 2.5 |

**Notes:**
a. Numbers are calculated from data on gross immigration in Australia, Canada, New Zealand, and the United States.
b. The periods from 1850 to 1960 pertain to emigration only to the United States.
c. Emigration only to the United States.
**Source:** The World Bank, 1984, Reference 18, p. 69.

## Unmet Need for Contraception

The WFS found that many women were having more children than they said they wanted. Women in the survey responded to a question that asked how many children they would have "if they could choose exactly." In Latin America, women would have two or three fewer children if they could choose. In Asia and the Pacific, women were also having more children than they wanted; the desired number of children in Bangladesh was 4.1 per woman, while the average woman actually had 7.5. In North Africa, the trend held true. All told, of

## Box 2.2 The World's Fastest-Growing Population

Why do Kenyans have so many children? Africa has the fastest-growing population of any continent, and Kenya has the fastest-growing population in Africa. The average Kenyan woman has 8.1 children, although there are tentative signs that people may choose to have fewer children in the future (1,2).

Kenya's population of 20.6 million is growing at the rate of 4.1 percent per year. At that rate it will double in a mere 17 years. According to the United Nations medium projection, by 2025 Kenya will be home to 83 million people. Moreover, Kenya is a young country, with over 50 percent of the people under the age of 15 (3).

"Kenya represents a very crucial country with regard to population policies and programs, as Kenya's experience will likely affect other African countries," says Rafael M. Salas, Executive Director of the United Nations Fund for Population Activities (4).

Kenya's rapidly expanding population occupies a medium-sized country of largely arid or semi-arid land, only 20 percent of which is fertile farmland. Straddling the equator on the east coast of Africa, Kenya encompasses barren steppes, grassy plains, highlands, a lake region and a strip of coastline (5).

Most of the people are concentrated in the fertile 20 percent of the country, where they work the land. As population pressures build, readily exploitable farmland is becoming scarce. Increasing numbers of people try to farm marginal lands and fragile ecosystems that often turn to dusty wastes under the hoe and the plow. Swelling waves of rural migrants head for the cities, which are undergoing tremendous strains from overcrowding. The urban population is growing by 7.36 percent per year.

### POPULATION OUTSTRIPS ECONOMY

Kenya's population is outstripping its economy. The Kenyan gross national product grew at a healthy clip of 5 percent per year between 1975–83. But that just exceeded the country's population growth, which is increasing at the rate of 4.1 percent per year.

Calculations by the World Bank show that Kenya spent 32 percent of total government expenditure on education, health, rural water supply and urban housing during the period 1975–80. If current fertility rates continue, the country will need to spend almost nine times as much in the period up to 2015–20 just to maintain current standards. An estimated 11 million new jobs will have to be provided by the year 2000, in addition to those needed to accommodate present underemployment or unemployment (6).

The main reasons for the recent surge of growth are that more babies in Kenya are surviving the precarious first year of existence, and people are living longer lives. Although there have been some indications of increased fertility among younger women, most of the growth results from improved health and living conditions (7,8).

In the last century, people lived shorter lives due to famines, slave raids, and tribal wars. In the early part of this century, sleeping sickness, malaria, plague, and malnutrition contributed to a high mortality rate. Infants are believed to have died at the rate of perhaps five for every ten born.

By the time of the 1948 census, health conditions were considerably improved and for every ten births, about two infants died before the age of two. By 1985, the infant mortality rate had further declined to the rate of less than one death in the first year of life, for every ten births. Additional improvements are expected. For example, family planning enables women to lengthen the interval between births, and this improves the infant's chances of survival (9).

In Kenya, mothers whose babies are most likely to survive their first year are those who live in an urban area, are educated, do not live in polygamous unions, are not too young, and have not had more than five or six children (10).

The average Kenyan born in 1955 lived only 39 years while a Kenyan born today can expect to live 55 years. Though a substantial improvement, this is still a much shorter life than the average of 74 years a person born in the developed world can expect (11).

### NOT ONLY ROGUES AND ROBBERS

The question of why Kenyans continue to have so many children has not yet been completely answered, although it is attracting the interest of many researchers. An informal survey of health workers from many parts of the country revealed the following, highly personal replies:

- "Amongst many children there are likely to be not only rogues and robbers but also professionals such as doctors, lawyers, engineers, etc."
- "A wife continues to bear children to prove her continued fecundity to prevent the husband from marrying another wife."
- "Wives in polygamous families compete with each other to produce the largest number of children."
- "Children provide labor for fetching firewood and water and for digging in the fields."
- "Children are an investment as they provide old age security for the parents."
- "Women have no say in determining the size of the family" (12).

In general, most women have little status in Kenyan society unless they have children, preferably many children.

### FAMILY PLANNING PROGRAMS

An important question for the future is the extent to which Kenyans will adopt family planning. The government has supported family planning programs for almost a decade. "Although Kenya officially adopted family planning programs in 1966 with a view to reducing the rate of growth of population, this has not succeeded," says President Arap Moi. Recognizing the problem, the government established a National Council for Population and Development in December 1982. The Council has the primary responsibility of introducing information and education programs for the establishment of a small family norm.

The World Fertility Survey showed that Kenyan women with secondary or higher levels of education are likely to have fewer children. And according to the Kenyan Fertility Survey, younger women want fewer children than older women want (13).

These and other factors may signal the start of a transition toward lower fertility, but the trend is still unclear. Indeed, traditional practices that formerly served as a brake on fertility (such as breastfeeding and sexual abstinence for a long period following the birth of a child) are now less prevalent. At this stage, fertility may actually increase (14).

### References and Notes


1. U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982*, Population Studies No. 86 (United Nations, New York, 1985), Annexes.
2. R. A. Henin, *et al. Evaluation of Birth Histories: A Case Study of Kenya*, Scientific Report No. 36 (World Fertility Survey, Voorburg, the Netherlands, October 1982), p. 29.
3. *Op. cit.* 1.
4. R. M. Salas, United Nations Fund for Population Activities, New York, September 1985 (personal communication).
5. United Nations Fund for Population Activities, *Kenya: Report of Mission on Needs Assessment for Population Assistance*, Report No. 15 (United Nations Fund for Population Activties, New York, 1979).
6. World Bank staff (Working Paper) (unpublished).
7. W.H. Mosley, *et al.*, *The Dynamics of Birth Spacing and Marital Fertility in Kenya*, Scientific Report No. 30 (World Fertility Survey, Voorburg, the Netherlands, August 1982), p. 25.
8. F.L. Mott, *Infant Mortality in Kenya: Evidence From the Kenya Fertility Survey*, Scientific Report No. 32 (World Fertility Survey, Voorburg, the Netherlands, August 1982), p. 24.
9. *Op. cit.* 6.
10. *Op. cit.* 2.
11. *Op. cit.* 1.
12. United Nations Fund for Population Activities, field report (United Nations Fund for Population Activities, Africa Branch, unpublished, New York, 1985).
13. *Op. cit.* 7.
14. *Op. cit.* 7.

the women surveyed in 31 countries, about half did not want any more children. (See Figure 2.8.) However, in sub-Saharan Africa, women seemed to want as many children as they could have.

Thus, the WFS revealed a substantial, though widely varying, unmet need for modern contraception (33). The figure for rural Mexico was 58 percent of women aged 14–49, while in Asia it varied between 9 percent in the Yemen Arab Republic and 53 percent in Fiji. In Bangladesh, the Republic of Korea, Malaysia, and Thailand, it was about 30 percent. The figure for Ecuador, urban Mexico, Colombia, and Paraguay also stood at 30 percent. The lowest figures for unmet contraceptive need were found in Africa, from 5 percent in Benin to 21 percent in Egypt.

## Education and Fertility

The survey also showed that women in higher educational groups generally had fewer children than their counterparts with little or no education (34,35,36,37). Analysis of WFS data for 30 countries (38) showed, however, that a few years (one to three) of education seem to be associated with higher recent fertility rates, possibly due in some cases to the disruption of traditional contraceptive practices.

Many, but not all, countries show a direct and consistent relationship between increasing levels of education and decreasing fertility; these include Senegal, Tunisia, Costa Rica, the Dominican Republic, Jamaica, Panama, Peru, Venezuela, Jordan, Malaysia, Nepal, the Philippines, and the Republic of Korea.

In a few countries, there was a rise in fertility when higher levels of education were reached (nine or more years of schooling). This trend appeared in Ghana, Colombia, Paraguay, Bangladesh, Pakistan, Sri Lanka, and Sudan. This effect may be a result of higher levels of income, rather than higher education (39).

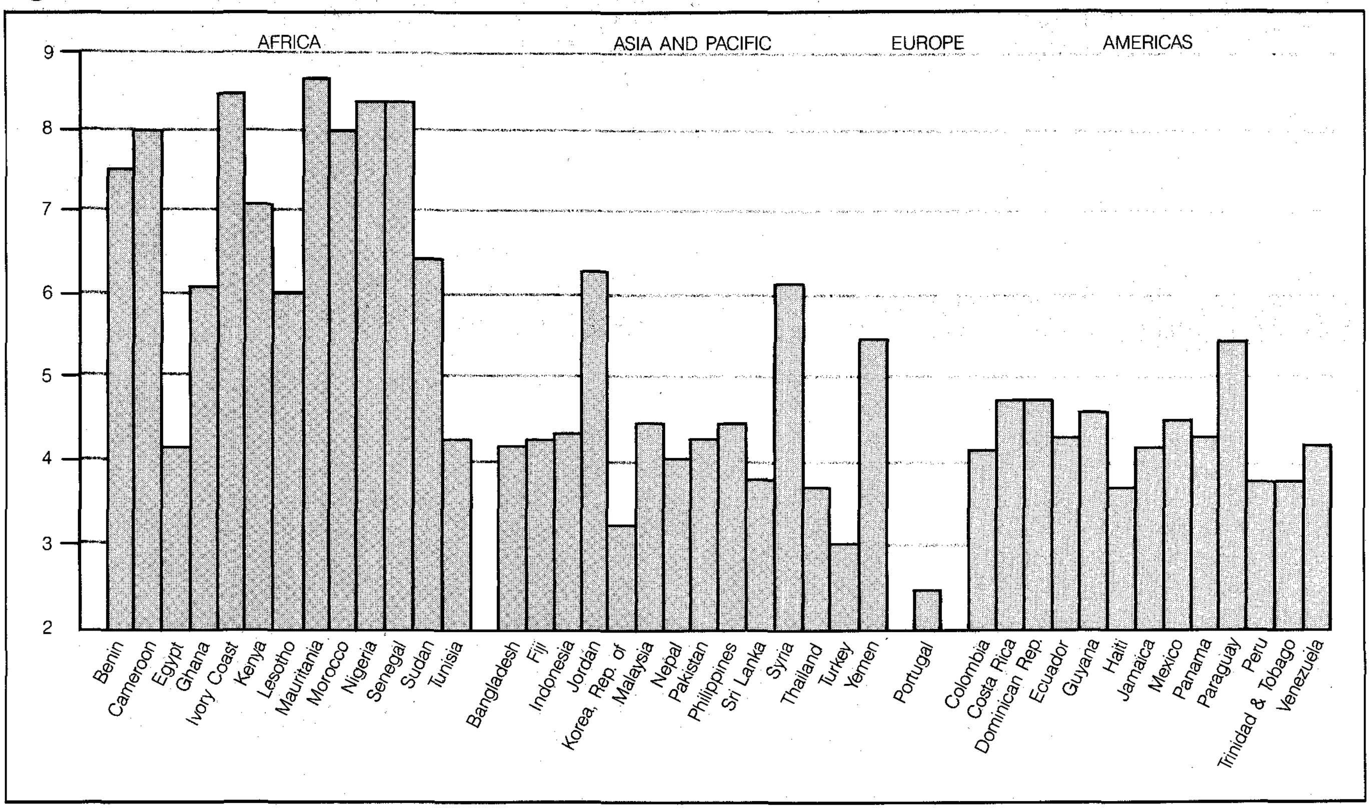
Although the patterns differ among countries, the results clearly demonstrate the importance of education in prompting lower fertility rates. In addition, the WFS showed that in general, the more education a woman had, the more likely she was to use an efficient rather than an unreliable method of contraception (40).

## Use of Contraceptives

Current contraceptive use shows striking regional variations among the 27 developing countries studied, with the highest use rates found in countries of Latin America and the Caribbean, followed by Asia and the Pacific. Use of effective means of contraception was especially low in Africa (other than North Africa), ranging from 1.0 to 4.5 percent of women in the study (41).

In China, Hong Kong, and Singapore, an estimated 71–72 percent of married women practiced some form of contraception at the time of the WFS. More than half the married women in Costa Rica, Panama, Puerto Rico,

**Figure 2.8 Number of Children Desired in Selected Countries**




**Source:** World Fertility Survey, *Fertility in the Developing World*, (International Statistical Institute, London, December 1984).

Jamaica, and Trinidad and Tobago were contraceptive users, as well as about half the married women in Lebanon, the Republic of Korea, Sri Lanka, and Thailand, and a quarter of the women in Egypt and Tunisia (42).

On the low end of the scale, the WFS found that only 5 percent of married women in Pakistan, 7 percent in Nepal, 8 percent in Kenya, and 13 percent in Bangladesh were using any means of contraception.

The largest recent increases in contraceptive use have occurred in Latin America and Asia. India and China were not included in the WFS, but it is known that use has increased substantially in China, and moderately in India.

In most of the 11 developed countries surveyed, contraception was used by about two thirds to four fifths of the married women. For example, the rate of use in the United States was 68 percent; in Japan, 61 percent; in Poland, 75 percent; and in France, 79 percent (43).

No method of fertility regulation is perfect for all individuals or cultures, but the variety of methods available has increased dramatically since the 1950s (44). Prior to 1900, few methods were widely available apart from the traditional ones of withdrawal, douching, delayed marriage, breastfeeding, and abstinence. A relatively unreliable version of the condom became available in the 19th Century. In the 1920s diaphragms with spermicides became available. The intrauterine device (IUD) was proposed in the early 1900s, but was not given serious consideration as an effective method until 1962. Initial human studies were conducted in 1957 for the use of oral contraceptives. Implants, injectables, and the vaginal ring are relatively recent developments.

In most developing countries, relatively effective methods of contraception are now predominant, while in a minority of countries less effective means are more commonly used. In Eastern and Southern Europe, traditional means—particularly rhythm and withdrawal (backed up by abortion in Eastern Europe)—account for about half of contraceptive practice, and in France, for about 40 percent. In other parts of Europe and in North America, more modern methods are chosen by the majority of users.

## Son Preference

Among the questions asked in 27 of the WFS countries was one concerning the preferred sex of the next child: "Would you prefer your next (or first) child to be a boy or a girl?" Pregnant women were asked the question, as were those in the survey who wanted at least one more child (45).

In the majority of countries surveyed, there was little or no gender preference. But in six countries, called the extreme son-preference group, about five women wanted a son for every woman who wanted a daughter. In general, women in the Caribbean, Central America, and Africa had no stated preference for sons or daughters, while women in Asia and the Arab countries of the Middle East exhibited strong or moderate son preferences.

To what extent does gender preference influence the number of children people have? Son preference appears to elicit a positive fertility response (people have more children than they would otherwise have) in Korea, Malaysia, Nepal, Pakistan, Fiji, Mexico, Paraguay, and Trinidad and Tobago. Where marital fertility is largely uncontrolled, an effect should not be possible no matter how strong the preference. In countries such as Pakistan and Nepal, analysts hypothesize that unrecorded birth control, or reduced coital frequency, may be responsible. In Jamaica and Haiti, daughter preference may influence fertility (46).

In countries where families are usually large, as in many African countries, the parents are liable to have both sexes represented among their offspring, and gender preference may not play a major role.

India and China were not included in the World Fertility Survey, but it is known that a strong son preference exists in both countries. The results of the WFS thus reinforce the concept that son preference is a widespread—though by no means universal—attitude that in some cases influences fertility behavior.

## Patriarchy and Fertility

The WFS gender preference data have been analyzed in relation to patriarchal family structure using the age difference between husband and wife as the measure (47). Patriarchal societies are generally characterized by a large age difference between spouses, the supremacy of the father in the clan or family, the legal dependence of children and wives, and the reckoning of descent and inheritance through the male line. By relating the median age differential between spouses to total fertility rates, the study showed a positive relationship between high fertility and a strong patriarchal structure. Fertility reduction in such societies appears to be much more difficult than in non-patriarchal societies.

Patriarchal structures have developed over thousands of years, (48,49,50) and although weakened considerably in many parts of the developed world, they continue to exert powerful influences over the lives of many women in the Third World. (See Box 2.3.) More research needs to be done to establish the mechanisms by which patriarchal societies regulate fertility decisions (51,52,53).

## Male Attitudes

Nearly all family planning programs are still formulated for women, but men are beginning to receive increased attention. However, the extent to which male views determine fertility decisions, and men's views concerning the number of children they would like to have, are still largely unknown.

A recent study of men aged 18–54 in Santiago, Chile, found that most men in that urban area and a neighboring village felt that men and women shared equally in fertility decisions (54). This contrasted with an earlier study of white-collar males of Sao Paulo, Brazil, where 86 percent of the husbands felt the man was mainly responsible for determining the number of children (55).

Although many observers have suggested that male dominance in Africa is partially responsible for high fertility rates, empirical data are scarce (56). There are,

## Box 2.3 A Way Out For Women In Bangladesh?

Where women have "no exit" from poverty and live under a strong patriarchal system, changes that would allow them more control over their own lives are not easily introduced or accepted. Bangladesh is an example of such a society. Yet the government of Bangladesh seems to have found a way. In 1974 a program was introduced to simultaneously provide an opportunity for rural women to engage in income-generating activities and to provide them with access to information on family planning, health, nutrition, and literacy training (1).

In rural Bangladesh, male dominance is established through control of material resources and through a series of reinforcing elements throughout the society. Men hold almost all the positions of power; they dominate the political and legal institutions, and legal protection of women is nominal. The religion of Islam calls for the sexual division of labor and in effect may be interpreted as sanctifying male dominance.

When a Bangladeshi woman marries, she moves to where her husband lives, and has reduced contact with her own family. Arranged marriages and age differences between husband and wife of about ten years, on the average, place her in a subordinate position.

Women in Bangladesh are generally subjected to *Purdah*, whereby they are restricted to their home compounds, and are required to wear clothing that conceals both form and face. Thus it is not easy for them to work outside the home, and they are denied income-earning opportunities. However, they put in long hours of household work.

Women are heavily dependent on their husbands for support, and if the husband should die before the wife (as is usual, because of age differences between spouses), the woman becomes dependent on her son. Thus there is a strong incentive for a woman to produce sons, not only to please her husband and family, but to secure her own social and economic future. Without sons to rely on, widowhood, divorce, or abandonment can leave a woman destitute.

Parents consider sons necessary to inherit and maintain control of land (2). Under Muslim law a daughter can receive only one half the share of an inheritance received by a son. Without a male guardian, women run the risk of losing any land they do inherit.

About 90 percent of the people in Bangladesh work in agriculture, and about 80 percent of the cultivable land is in production (3). Children start working early, helping with household and agricultural tasks: 60 percent of the boys and 90 percent of the girls start working by the age of ten, and by the age of 12 nearly all of them join the family labor force. Compulsory primary education would no doubt change this pattern (4).

A government report published in 1981 indicated that 11 percent of married women in Bangladesh were using some method of contraception at the time of the study (5). An official family planning program has been in operation since 1962 (6).

The total fertility rate, though falling, is still high—6.15 during 1980–83—and the country's population growth rate for that period was 2.74. In 1985, the estimated population was 101 million. By the year 2020 it may have more than doubled to 206 million, according to U.N. estimates (7).

### WOMEN'S COOPERATIVE PROJECT

In 1974, the Women's Cooperative Project, a part of the government's Integrated Rural Development Program, started establishing cooperative associations for rural village women. Membership in a cooperative costs about ten cents, and women are required to deposit their savings weekly, attend weekly village cooperative meetings, and send representatives to a training and development center every week. There they are provided with modern training, supplies, services, and improved family planning and health programs. Topics may include poultry raising, horticulture, hygiene measures, or loan policy. Once the village leaders have endorsed a local cooperative, the members are entitled to credit for individual and group economic enterprises (8).

The cooperative decides who should receive loans as well as the size of the loans. Women have taken loans for the processing of mustard oil, chili, turmeric, fish, and peanuts; the purchase of livestock and poultry to raise and sell; the financing of small enterprises such as pottery-making; or to buy water or lease land for cultivation (9). So far, demand has far outstripped resources. Repayment rates have been very high, approaching 100 percent.

From 1974–84, the women's cooperatives expanded to cover 100 of the 473 *thanas* (or administrative units) in Bangladesh. As of December 1984, the government program was assisting 1,700 cooperatives with 67,000 members. Estimated project costs for the period 1980–85 are between $2 million and $2.5 million.

The project had a population goal as well as an economic one. As described by its first director, the project was "based on the clear assumption that rural women are responsible people whose contraceptive behavior is part of their total response to their culture. The major effort of this project, therefore, has to be to explore ways to bring about changes in their culture, so that contraception could be an acceptable choice," and to make that choice available to them (10).

The Integrated Rural Development Program was seeking to slowly bring about fundamental changes in the lives of rural women, in which the decision whether to practice contraception is part of a complex fabric involving economic insecurity, social exposure, family prestige, and other factors (11).

Again, in the words of the project's founders, "the presence of 50 village women of varying ages, both unmarried and married, in a classroom to learn about contraception and discuss their problems, represents a great change in rural areas and offers an important opportunity for the government to reach a large number of rural women and to improve its services to them" (12).

A July 1983 study indicated that 66 percent of all eligible cooperative members had accepted family planning. Those classified as "eligible" included all women aged 15–44, married, with husband present, who had not given birth in the last six months. This compares with an acceptance level of 34 percent at a family-planning health services project that did not have an economic development component (13,14).

Although the 66 percent acceptence rate for the Women's Cooperative Project is an impressive accomplishment, the project goal is a further 25 percent increase in the number of women using contraception. Plans for the next five years call for an expansion of the program to double the number of women covered, and double the members' average income to $93.

#### References and Notes


1. J. Bruce, "Income Generation Scheme: The Bangladesh Experience," *Populi* 12, No. 2, pp. 38–49 (1985).
2. M. Chain, "The Economic Activities of Children in Villages in Bangladesh; A Report of a survey in Char Gopalar village, North Central Bangladesh," *Population and Development Review*, Vol. 3, No. 3, pp. 201–228 (1977).
3. R. Amin and R. Faruqee, *Fertility and its Regulation in Bangladesh*, World Bank Staff Working Paper No. 383 (The World Bank, Washington, D.C., 1983), p. 1.
4. M. Aluddin and R. Faruqee, *Population and Family Planning in Bangladesh*, World Bank Staff Working Paper No. 557 (The World Bank, Washington, D.C. 1983), p. 17.
5. *Op. cit.* 3, p. 13.
6. *Op. cit.* 2, p. 1.
7. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* Population Studies, No. 86 (United Nations, New York, 1985), Annexes.
8. *Op. cit.* 1.
9. Integrated Rural Development Program, *Population Planning and Rural Women's Cooperatives*, (Integrated Rural Development Program, progress report on pilot project, 1975–79, Bangladesh, May 1980).
10. *Op. cit.* 3.
11. *Op. cit.* 1.
12. T. Abdullah and S. Zeidenstein, *Village Women of Bangladesh: Prospects for Change* (Pergamon Press, Oxford, 1982).
13. *Op. cit.* 1.
14. J.F. Phillips, *et al.*, "The Demographic Impact of the Family Planning Health Services in Matlab, Bangladesh," *Studies in Family Planning*, Vol. 13, No. 5, p. 138 (1982).

however, some examples that contradict the stereotype that men want many children to prove their masculinity, are negatively disposed to family planning and unwilling to use birth control, and have little concern for the well-being of their partners (57).

A project sponsored by the government of Ghana in the early 1970s organized mobile family planning teams in the Danfa region north of Accra, the capital city. Traveling from village to village to provide birth control services, these units were supplemented by maternal and child health care centers and by primary care health workers in the area.

Although originally intended as a program for women, it soon became apparent that half the clients were men. The men in the male-dominated Danfa society became more conscientious users than the women, and were persuasive advocates of contraception. Fertility was reduced in the Danfa area, and it was estimated that about half of the reduction was accounted for by the men's acceptance of contraception.

### Employment and Fertility

World Fertility Survey data for 30 countries show that women working away from home in the urban or modern market economy, and those in higher-status occupations, had fewer children than other women in their respective countries. Women in low-paying, low-status jobs were likely to have fertility rates as high as or higher than women who had never worked. Women working in agricultural jobs also had higher fertility levels (58).

In most of the developing countries surveyed, fertility was higher for women who had not worked since marriage than for women who had worked at home or away from home. Contrary to expectations, in almost half of the countries, women working away from home had higher fertility than did those who worked at home.

However, the relationship between fertility and work is a very complex one, for a variety of reasons. First, the concept of "work" differs considerably among countries. Fertility, family size, age, and other factors affect the likelihood of participation in the labor force, and *vice versa*. And finally, the distinction between "not working" and "working at home" was often blurred, perhaps due to differing cultural definitions of "work." The WFS generally considered work in addition to the usual housework, but even this distinction was not clear, for in some countries it included work on the family farm and in others it did not (59). In industrialized countries there is a stronger and more consistent relationship between women's work and fertility, with working women having fewer children (60).

### Urban-Rural Differentials

City life is evidently conducive to smaller families, according to analysis of World Fertility Survey data from 29 developing countries. Women in the study were categorized as residing in one of three types of areas: major urban areas (cities with a population exceeding one million, and capital cities), other urban areas, and rural areas. The distinction between "other urban areas" and "rural areas" is unclear, as countries use different definitions. (See Chapter 3, "Human Settlements.")

Nevertheless, the study showed that fertility rates in rural areas were higher than in urban areas in nearly all countries (61,62). In a few countries in Africa and Asia, little difference emerged between rural and urban areas. The results were adjusted to take account of such factors as the women's age, education, age at marriage, work status, and occupation of husband. In some countries, as in Kenya and Venezuela, rural women bore 40 to 50 percent more children than urban women. The only country where urban women were more fertile was Pakistan, where they produced 15 percent more children than their rural counterparts.

### Summary

Fertility is an extremely complex behavior, influenced by dozens of factors. Recent research shows clearly that in addition to access to effective means of contraception, cultural and socioeconomic change are important. In particular, new opportunities for women—through education and a higher status within the family and outside the home—play unmistakable roles in lowering fertility.

## MIGRATION

Over the past half century, the character of international migration has changed. Where in the past the international migrant stream was primarily made up of Europeans who settled in the New World, most migrants now come from Asia and Latin America (63,64).

Today, although the United States has taken increasing numbers of immigrants, there are fewer permanent places available for migrants in the three other traditional immigration countries: Canada, Australia, and New Zealand. Other target areas have opened up for foreign workers, particularly in the oil-rich countries of the Middle East.

Labor migration to Western Europe was strong up to the early 1970s (65,66). During just one decade, more than 30 million foreign workers, primarily from Mediterranean countries, migrated to Western European countries, after a European Economic Community (EEC) regulation granted member states the right to recruit migrant workers from countries outside the EEC. In 1973, one seventh of the Western European labor force consisted of foreign workers.

The economic recession that followed the oil crisis of 1973–74 disrupted migration patterns, and many of the migrant workers returned home. The European host countries tightened their policies with regard to admission of migrant workers, but continued to accept permanent immigrants and refugees (67). One consequence was illegal migration. Pressed by population growth and unemployment in their home countries, many migrants sought and found illegal means of reaching their goals. Overall, however, the flow of migrants to Western Europe since 1974 has remained relatively small (68).

In Africa, large flows of refugees have constituted the major form of migration. Few African governments have accepted permanent migrants on any large scale, though some Arab countries allow substantial numbers of foreign workers (69). In Asia, there is currently very little immigration for permanent settlement but there has been large-scale labor migration to West Asia. In Latin America there is substantial intra-regional migration, much of it unauthorized. Venezuela is Latin America's major receiving country.

## POPULATION POLICIES AND PROGRAMS

When India included family planning in its First Five-Year Plan for 1951–56, it became the first government in the world to adopt a national family planning program. Since then, the perceptions of developing country governments have undergone an unprecedented change. Many governments that previously considered it unnecessary or even harmful to introduce population policies have reversed their positions as the impacts of population growth on socio-economic development have become apparent. By 1984, 80 of the 126 developing countries had official family planning programs, according to one estimate. In addition, 14 other countries indirectly supported family planning information through private or semi-governmental agencies (70).

Most developing country governments finance about half the cost of family planning programs in their countries, with external assistance providing the balance. In China, the government finances nearly all the cost of its program, and India finances 80 percent of its program. (These two countries together account for nearly 40 percent of the world's population.)

In 1980, China spent about $1 and India spent about 30 cents per capita on population programs. Other developing countries for which data are available spent within this range. If other developing countries were spending equivalent amounts, the total for the Third World at that time was about $2 billion. Overall, the amounts spent, in relation to other government outlays are tiny: less than 1 percent (71).

Population programs also account for only about 1 per cent of external assistance funds, a mere $500 million. During the 1970s, external assistance increased by about 6 percent a year, but it fell by 3 percent in 1980 and by 6 percent in 1981 (72). The United Nations Fund for Population Activities (UNFPA), a major source of external assistance, is troubled by uncertainties regarding contributions by the United States, traditionally UNFPA's largest donor. (See "Recent Developments," below.)

Private suppliers provided about a quarter of family planning services; in some countries or regions—such as Korea, and Latin America—they play a more dominant role.

Taking into account all public spending on family planning in developing countries—including spending for contraceptive services; program administration; information, education, and communications activities; research and evaluation; and personnel training—the per capita cost averages about 70 cents a year. However, only a small percentage of Third World people—most of them in India and China—use contraceptives, so the average cost per user is higher: about $11. If private expenditures in all developing contries were added, the cost per user would probably be double that amount (73).

The costs of meeting the unmet need for contraception have been estimated by the World Bank at roughly $1 billion in additional annual public spending (74).

However, the number of women of childbearing age is increasing (from 500 million in 1980 to 700 million in 2000) and a growing fraction is expected to want to use modern contraceptives. If a "rapid" fertility decline to a total fertility rate of 2.4 were to be reached by the year 2000, the World Bank estimates that 72 percent of married women of reproductive age in developing countries would have to be contraceptive users, up from 40 percent today. The sum required for such a decline, assuming the 1980 cost per user, would be $7.6 billion in annual public spending by the year 2000, an increase in real terms of 7 percent a year (75).

## RECENT DEVELOPMENTS

### THE INTERNATIONAL CONFERENCE ON POPULATION

One of the indicators of the increased commitment to population programs was the remarkable international consensus that characterized the August 1984 International Conference on Population, held in Mexico City. In contrast to the first World Population Conference, held in Bucharest in 1974 at the urging of the developed nations, the Mexico City meeting was convened at the request of the developing countries, several of whom vied for the privilege of hosting it. Whereas at Bucharest—a meeting marked by major confrontations between developed and developing countries—key developing countries argued that "development is the best contraceptive," at Mexico City virtually no one questioned the principle that population policies and programs are integral elements of economic development.

The policy position adopted by the U.S. delegation barely fit within this consensus, even after much compromising between U.S. conservatives opposed to population control programs and elements within the U.S. Government traditionally supportive of Third World family planning programs. While arguing that interference with free markets—not population growth—was the source of economic problems in the Third World, the U.S. policy statement did agree that rapid population growth compounds already serious economic and social problems. It affirmed U.S. support for voluntary family planning programs in the Third World as an ingredient in a comprehensive effort to address root causes of poverty, but announced that the United States would not support coercive population control programs nor provide assistance to multilateral or nongovernmental organizations that perform or promote abortion.

However, the U.S. position appeared to have made little impact on the set of 88 recommendations adopted by the representatives of the 146 governments participating in the conference. It is even possible that the controversial U.S. position made it easier for many nonaligned countries to subscribe openly to the principles and approaches laid out in a strengthened "World Population Plan of Action." The same dynamic may have been at work in July 1985 at the International Women's Conference in Nairobi where Third World women aggresively challenged western anti-abortion and natural family planning activists and reconfirmed the major recommendations of Mexico City on family planning and the status of women. (See Chapter 4, "Food and Agriculture," Recent Developments.)

The recommendations of the Mexico City conference affirmed that governments have a responsibility to make universally available the information and means for couples and individuals to make decisions about the number and spacing of their children. The conference also deplored coercion, and agreed that abortion should not be promoted as a method of family planning.

A full section was included in the recommendations on measures needed to protect and enhance the status of women, and special attention was urged for maternal and child health care. Other recommendations covered integrated development strategies, the importance of nongovernmental organizations, the rights of migrants, and programs for the elderly and youth. As summarized in the Declaration of Mexico, the deliberations of the 1984 Population Conference were a high-water mark in the 30-year struggle for worldwide population awareness (76).

## POLICY SHIFTS IN THE UNITED STATES AND ELSEWHERE

Within the United States there has been a perceptible slackening of traditional support for international population programs. Although the U.S. Congress steadily increased funding for U.S. population assistance from $190 million in 1981 to $290 million in 1985, budget levels for 1986 and 1987 are likely to decline.

In December 1984, the U.S. Agency for International Development (U.S. AID), in keeping with new U.S. anti-abortion policies announced at Mexico City, ended its 18 years of support for the International Planned Parenthood Federation (IPPF). The $17 million in U.S. cash contributions and contraceptive commodities represented one quarter of IPPF's budget. Plans for new national family planning programs, including 13 new affiliates in Africa, were canceled.

Early in 1985, U.S. contributions to the United Nations Fund for Population Activities also came under attack because of UNFPA support for programs in the People's Republic of China. The U.N. Fund for Population Activities is the largest source of multilateral assistance to population programs and operates in over 100 countries. The U.S. Agency for International Development withheld $10 million from a $46-million contribution pledged to UNFPA and earmarked by Congress. In 1985, Congress prohibited U.S. support for any organization that "participates in the management of a program of coercive abortion or involuntary sterilization." Future U.S. contributions to UNFPA are in jeopardy, as are contributions to other organizations with programs in China and in some half-dozen other countries where accusations of coercion have been made.

Other policy shifts are gradually changing the profile of United States population assistance abroad. As longtime grant agreements with major nongovernmental family planning organizations come up for renewal, U.S. AID is insisting on new contract language. Some organizations have signaled that they cannot comply and will fall out of the program. Such private groups now work in some 70 countries, compared to direct U.S. government-to-government programs in only 30 countries. Private sector programs are also generally more innovative and cost-effective. Since 1981 U.S. AID has also increased 20-fold (from $400,000 to $8 million) its support for natural family planning—methods that rely on sexual abstinence for up to half the menstrual cycle. These programs have been exempted from U.S. AID's longstanding requirement that family planning services describe all available contraceptive choices.

Outside the United States the general trend has been a strengthening of government commitment to population and family planning programs. Other donor nations such as Germany and Japan have steadily increased their external assistance for population, despite level funding for other sectors in some cases. In 1985, a few western donors consciously sought to make up part of the shortfall resulting from U.S. cuts to IPPF and UNFPA. Among the developing countries, Indonesia, Thailand, India, Pakistan, Bangladesh, Egypt, Sudan, Kenya, Nigeria, Mexico, Brazil, and at least a dozen others, are moving to expand and strengthen family planning services.

But there are also signs that population programs may soon be in political trouble in a number of countries, for some of the same reasons that have caused debate in the United States: the resurgence of religious fundamentalism; public concerns over abortion, sexual promiscuity, and threats to the family; questions about contraceptive safety; and a backlash against population control programs perceived to violate individual rights.

The examples are mounting. In 1985 Sweden withdrew from the World Bank donor consortium for Bangladesh's population program, citing objections to incentive payments for sterilization and insufficient attention to primary health care. Conservatives in Great Britain and Canada have threatened to withdraw support by those countries for the International Planned Parenthood Federation over the abortion issue and services for adolescents.

In a number of developing countries indigenous anti-family planning movements are also on the rise, sometimes aided by organizations based in western countries. In Mexico, Guatemala, Peru, El Salvador, and the Philippines, conservative Catholic groups have challenged national family planning programs with mixed results. In Egypt, Iran, Sudan, and Pakistan, Moslem fundamentalists have moved against both family planning and recent measures to improve the status of women. Opponents of family planning argue that western donors are dumping dangerous contraceptives on unsuspecting Third World women and promoting population control in order to contain the growth and power of non-white populations.

## RECENT TRENDS IN INFANT MORTALITY

The 1980s have been harsh years for vulnerable populations, and especially hard on infants and children, whose survival often depends on the availability of medical care for mother and child in the critical months before and after birth. In a broader sense, it also depends on economic conditions that affect pregnant and nursing women's nutritional status, the availability of adequate housing and water supplies, and the stability of household incomes. On all counts, conditions have deteriorated in many parts of the world.

Throughout most of sub-Saharan Africa, per capita food supplies and household incomes have fallen. In most of Latin America, the debt crisis has forced severe economic retrenchment that has reduced per capita incomes and government spending for public health and welfare. Even in industrial countries such as the United States and the Soviet Union, economic conditions and shifts in government programs have affected infants' chances for survival (77).

Thus, throughout much of the world, the slowdown in the pace of infant and child mortality improvements that was already evident in the 1970s has apparently continued into the 1980s. From the 1960s to the 1970s, the gains in infant mortality decelerated somewhat by comparison with the previous decade. The change was centered in Latin America, but was also evident in Africa (78). Events in China, as well as in the rest of Asia, ran markedly counter to this trend. Subsequent analysis has suggested that only part of the observed slowdown can be explained by the slower pace of developing countries' economic growth in the later period. The rest must be attributed to a marked decline in mortality improvements unrelated to improvements in income, literacy, and food supply (79). Throughout the earlier postwar period, these gains, due mainly to better medical services and technologies, had been responsible for as much as half of the overall improvement in infant and child mortality. However, in the 1970s this trend decelerated by as much as two thirds.

Although there are not yet sufficient data to assess the situation in the 1980s comprehensively, recent estimates of infant mortality in countries where vital registration data are reasonably reliable suggest that the slowdown has continued. In Costa Rica, for example, where the infant mortality rate fell from 34 per thousand in 1970–75 to 20 per thousand in 1980, it remained at 18.6 per thousand in 1983. In Argentina, where the infant mortality rate had fallen from 58 per thousand in 1970–71 to 33 per thousand in 1980, it dropped to 28 per thousand by 1983. In Barbados, the decline was from 34 to 23 deaths per thousand in the 1970s, but no further fall was recorded by 1983. In Cuba, the rate fell from 36 to 20 in the 1970s, and by 1983 it reached 16.8, a somewhat slower rate of decline. In Panama, the fall during the 1970s was from 52 to 22, and in 1983 the recorded rate was 20.4. In Chile, however, a similar comparison shows the decline from 82 to 32 in the 1970s and a fall to 22 by 1983, which maintains the rapid improvement (80). Overall, the indicators available suggest that mortality gains have slowed so far in this decade.

These indications are reinforced by recent trends in the United States, where the rate of fall in infant mortality declined from 4.6 percent per year in the late 1970s to 2.6 percent in 1983 and 1984 (81). The reasons are complex. The sharpest declines in U.S. infant mortality occurred in the 1970s, when programs to improve family welfare (including Aid to Families with Dependent Children, food stamps, and Medicaid), health, family planning, and abortion services were all more widely extended. Advances in medical techniques of caring for premature and abnormal infants also took place, as did important economic gains for households near the poverty line.

Among the explanations advanced for the slowdown in infant mortality gains are the increasing numbers of teenage and out-of-wedlock births; the cutbacks in family planning, abortion, and welfare programs; an increase in the number of households below the poverty line; and increases in the percentages of younger women who use tobacco and alcohol.

## References and Notes


1. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982,* Population Studies No. 86 (United Nations, New York, 1985) p. 11.
2. *Ibid.*, Annexes.
3. P. Hauser, Ed., in *World Population and Development* (Syracuse University Press, 1979), p. 3.
4. *Op. cit.* 2.
5. G. McNicoll, "Consequences of Rapid Population Growth: An Overview and Assessment", *Population and Development Review*, Vol. 10, No. 2, pp. 180–81 (1984).
6. Department of International Economic and Social Affairs, *World Population Prospects as Assessed in 1980*, Population Studies No. 78 (United Nations, New York, 1981).
7. Department of International Economic and Social Affairs, *World Population Prospects as Assessed in 1963*, Population Studies No. 78 (United Nations, New York, 1963).
8. J. W. Kincher, *et al.* "Carrying Capacity, Population Growth and Sustainable Development," *Rapid Population Growth and Human Carrying Capacity*, D.J. Mahar, Ed., The World Bank Staff Working Paper No. 690, Population and Development Series No. 15 (The World Bank, Washington, D.C., 1985), p. 49.
9. United Nations, *Report of the United Nations World Population Conference, 1974 Bucharest, 19–30, August 1974* (United Nations, New York, 1974).
10. D. Pitt, "People, Resources, Environment and Development in the Himalayas" in *United Nations Environment Program Expert Group Meeting* (United Nations, New Delhi, India, April 1985).
11. H. Brookfield, "Population, Development and Environmental Relations in Planning in Eastern Fiji and Eastern Caribbean: MAB Methodology and the Problems of Change through Time" in *Ecology in Practice*, F.D. Castri, *et al.*, Eds., (Tycooly Press, Dublin, 1984).
12. L.R. Brown, "World Food Resources and Population: The Narrowing Margin," *Population Bulletin*, Vol. 36, No. 3 (Population Reference Bureau, Inc., Washington, D.C., September 1981).
13. C. Freemand and M. Jahoda, *World Futures: The Great Debate*, (Universe Books, New York, 1978).
14. T. Frejka, "Long-Term Prospect for World Population Growth," *Population and Development Review*, Vol. 7, No. 3, pp. 489–511 (September 1981).
15. World Bank, *World Population Projections 1984: Short-and Long-Term Estimates by Age and Sex with Related Demographic Statistics* (World Bank, Washington D.C., 1984).
16. *Op. cit.* 2.
17. United Nations Secretariat, "Long-Range Global Projections, as Assessed in 1980",

*Population Bulletin of the United Nations*, No. 14, pp. 17–30. (1982).
18. World Bank, *World Development Report 1984* (World Bank, Washington, D.C., 1984), p. 73.
19. *Op. cit.* 14, pp. 489–511.
20. Department of International Economic and Social Affairs, *World Population Trends, Population and Development Interrelations and Population Policies*, 1983 Monitoring Report, Volume 1 (United Nations, New York, 1985), p. 145.
21. *Ibid.*
22. Jaques Vallin, "Socio-Economic Determinants of Mortality in Industrialized Countries", *Population Bulletin of the United Nations*, No. 13, pp. 26–41 (United Nations, New York, 1983).
23. Department of International Economic and Social Affairs, *Mortality and Health Policy* (United Nations, New York, 1984), pp. 146–168.
24. *Op. cit.* 18, p. 58.
25. J. Peterson, "Global Population Projections Through the 21st Century: A Scenario for this Issue", *AMBIO* Vol. 13, No. 3, pp. 136–137 (1984).
26. T. Shuman, "The Aging of the World's Population", *AMBIO* Vol. 13, No. 3, pp. 175–181 (1984).
27. P. O'Keefe, *et al.*, "Fewer Jobs - More Work? Structural Changes and Employment in the Late Twentieth Century", *AMBIO* Vol. 13, No. 3, pp. 189–196 (1984).
28. Repetto, "Population, Resource Pressures, and Poverty" in *The Global Possible*, R. Repetto, Ed. (World Resources Institute, Washington, D.C., 1985), p. 137.
29. *Ibid.* pp. 159–165.
30. *Op. cit.* 17, p. 19.
31. World Fertility Survey, *Major Findings and Implications* (International Statistical Institute, London, 1984).
32. Department of International Economic and Social Affairs, *Fertility and the Family* (United Nations, New York, 1984) pp. 45–47.
33. *Op. cit.* 31. According to the World Fertility Survey: "When a women does not wish to be pregnant and is either at substantial risk of pregnancy but is using no contraception or is using an inefficient method with a high rate of failure or has an unwanted pregnancy, it seems unreasonable to regard her as having 'unmet needs' for modern contraception".
34. *Op. cit.* 31.
35. Department of International Economic and Social Affairs, *Relationships Between Fertility and Education: A Comparative Analysis of World Fertility Survey Data for Twenty-Two Developing Countries* (United Nations, New York, 1983).
36. E.F. Jones, World Fertility Survey, *Socio-Economic Differentials in Achieved Fertility*, Comparative Studies No. 21 (International Statistical Institute, Voorburg, the Netherlands, 1982).
37. J.B. Casterline, *et al.*, *The Proximate Determinants of Fertility*, World Fertility Survey, Comparative Studies No. 39 (International Statistical Institute, Voorburg, the Netherlands, 1984).
38. *Op. cit.* 20.
39. *Op. cit.* 20.
40. A.A. Sathar and V.C. Chidambaram, *Differentials in Contraceptive Use*, World Fertility Survey, Comparative Studies No. 36 (International Statistical Institute, Voorburg, the Netherlands, 1984).
41. *Ibid.*
42. *Op. cit.* 20.
43. *Op. cit.* 20.
44. M.J.K. Harper, *Birth Control Technologies: Prospects for the Year 2000* (University of Texas Press, Austin, 1983).
45. J. Cleland, *Preferences for the Sex of Children and Their Influence on Reproductive Behavior*, World Fertility Survey, Comparative Studies No. 27 (International Statistical Institute, Voorburg, the Netherlands, 1983).
46. *Ibid.*
47. M. Cain, *Women's Status and Fertility in Developing Countries*, World Bank Staff Working Paper No. 682, Population and Development Series No. 7 (World Bank, Washington, D.C., 1984).
48. D. Schneider and K. Gough, Eds., *Matrilineal Kinship* (University of California Press, Berkeley, 1973).
49. M. Stone, *When God Was a Woman* (Harcourt Brace Jovanovich, New York, 1976).
50. E. Reed, *Women's Evolution, from Matriarchal Clan to Patriarchal Family* (Pathfinder Press, New York, 1975).
51. K.O. Mason, *The Status of Women: a Review of its Relationships to Fertility and Mortality* (Rockefeller Foundation, New York, 1984).
52. M.A. Koenig, G. H-G Foo, "Patriarchy and High Fertility in Rural North India" in *The Rockefeller Workshop on Women's Status and Fertility, June 25–28, 1985* (Mt. Kisco, New York, 1985).
53. S.R. Khandker, *Women's Role in Household Productive Activities and Fertility in Bangladesh* (Economic Growth Center, Yale University, May 1985).
54. M. F. Hall, "Family Planning in Santiago, Chile: The Male Viewpoint", *Studies in Family Planning*, Vol. 2, No. 7, pp. 143–147 (1971).
55. O.F. Baptista, *et al.*, *Attitudes Masculinas Em Relacão A Fecundidades E. Tamanho da Familia* (Fundacão Escola da Sociologia de Politica de São Paulo, Brazil, 1967), p. 69.
56. E. Boohene, "Promoting Women's Status," *Populi*, Vol. 12, No. 1, p. 30 (1985).
57. B. Stokes, *Men and Family Planning*, Worldwatch Paper No. 41 (Worldwatch Institute, Washington, D.C., December 1980).
58. U.N. Department of International Economic and Social Affairs, *Women's Employment and Fertility*, Population Studies No. 96 (United Nations, New York, 1985).
59. *Ibid.*
60. *Op. cit.* 20.
61. *Op. cit.* 36.
62. I. Alam and J. Casterline, *Socio-Economic Differentials in Recent Fertility*, World Fertility Survey, Comparative Studies (International Statistical Institute, Voorburg, the Netherlands, May 1984).
63. *Op. cit.* 2.
64. Department of International Economic and Social Affairs, *International Migration Policies and Programmes in Migration: World Survey*, Population Studies No. 80 (United Nations, New York, 1982)
65. *Op. cit.* 20.
66. *Op. cit.* 64.
67. Intergovernmental Commission for Migration, *The World-wide Situation and Problems of Undocumented Migration: Population Distribution and Development* (United Nations Department of International Economic and Social Affairs, New York, 1984)
68. *Op. cit.* 64.
69. *Op. cit.* 20.
70. U.N. Department of International Economic and Social Affairs, *World Population Trends and Policies, 1981 Monitoring Report* (United Nations, New York, 1981), Chapter 19, Table 19.
71. *Op. cit.* 18, p. 148.
72. *Op cit.* 18, p. 148.
73. *Op cit.* 18, p. 148.
74. *Op cit.* 18, p. 152.
75. *Op cit.* 18, p. 152.
76. United Nations, *Report of the International Conference on Population, 1984, Mexico City, August 6-14, 1984* (United Nations, New York, 1984).
77. For the deterioration in infant mortality in the Soviet Union, see E. Jones and F. Grupp, "Infant Mortality in the Soviet Union," *Population and Development Review*, Vol. 9, No. 2, pp. 213–247 (June 1983).
78. U.N. Department of International Economic and Social Affairs, "Infant Mortality: World Estimates and Projections," *Population Bulletin* No. 14, (United Nations, New York, 1982).
79. J. DaVanzo, *et al.*, *Quantitative Studies of Mortality Decline in the Developing World*, World Bank Staff Working Paper No. 683 (World Bank, Washington, D.C., 1985).
80. U.S. Bureau of the Census and the Pan-American Health Organization, unpublished data.
81. C.A. Miller, "Infant Mortality in the U.S.," *Scientific American*, Vol. 253, No. 1, pp. 31–37 (July 1985).

# 3. Human Settlements

For more than 200 years, the world's population has tended to concentrate in a relatively small part of the earth's surface—in towns and cities. But the pace of this process—called urbanization (1)—has accelerated sharply during the 20th Century. In 1985, urban dwellers comprised an estimated 41.6 percent of the world population, compared with 33.6 percent in 1960 and 13.6 percent in 1900. During the past 25 years, virtually all countries have experienced an increase in the proportion of the population living in urban centers.

Another gauge of the extent to which urbanization is increasing is the number of major cities. In 1980, there were about 230 cities with a population of 1 million or more, compared with only 13 in 1900. (See Figures 3.1A and 3.1B.) In most Third World countries, the urbanization of the past few decades has been concentrated in a few key metropolitan areas or "core regions." These not only contain a significant proportion of a nation's population, but also dominate the national economy, often to the detriment of residents of outlying areas. The mushrooming populations of the major urban centers can overwhelm a developing country's ability to provide housing, sanitation, and other important services. A common side effect of increasingly crowded conditions is severe pollution.

While urbanization has been the most significant feature of trends in the distribution of the world's population during the last century or so, a global view of this phenomenon can obscure the tremendous diversity in patterns of human settlement and the complicated mix of local, regional, national, and international factors that underlie these patterns. (See Figures 3.2A, 3.2B, and 3.2C.) Changes in the countries of the Third World, for example, are often markedly different from those taking place in First World or Second World nations. (See Table 3.1.) And even within the Third World, the type and degree of changes can vary greatly among nations, as well as among the cities and regions of a single nation.

Research on human settlements is often further complicated by the lack of data needed to assess changes in population distribution. Comparisons are also handicapped by data inconsistencies. For example, each nation has its own criteria for an "urban center," and differences in the criteria limit the validity of most international comparisons of levels of urbanization or growth rates of urban populations. (See Box 3.1.) Furthermore, definitions of metropolitan areas vary considerably, as do definitions of the central city in a metropolitan area (2).

This chapter focuses primarily on urbanization and only briefly discusses trends and conditions in rural areas, where the majority of the world population still lives. Human settlements for the world's rural population will be analyzed in depth in *World Resources 1987.* But because the urban system can be so extensive that it



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**Figure 3.2A Distribution of World Population in Cities of More Than 100,000 Inhabitants, 1980**

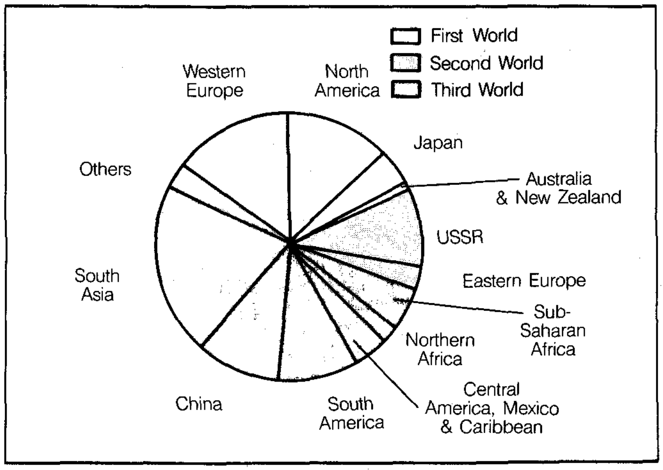



**Figure 3.2B Distribution of World Population in Cities of More Than 1 Million Inhabitants, 1980**

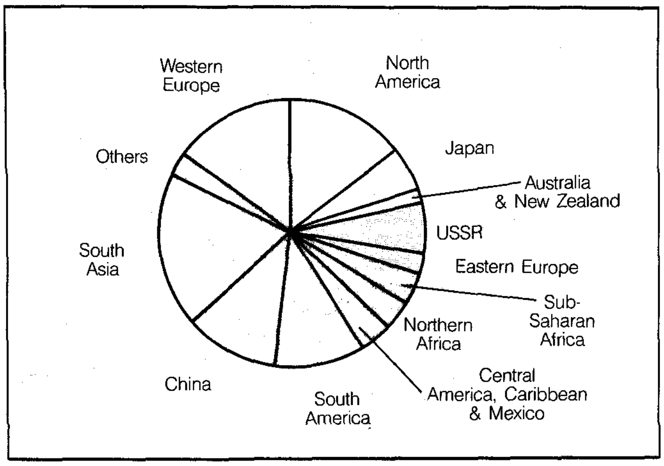
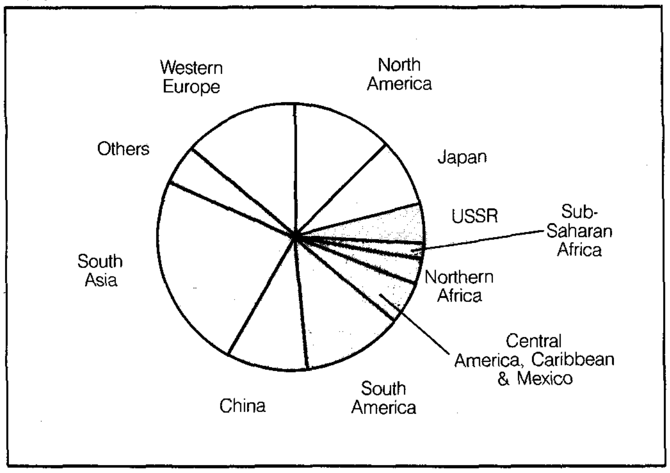



**Figure 3.2C Distribution of World Population in Cities of More Than 4 Million Inhabitants, 1980**




**Source:** Derived from United Nations (U.N.), *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment*, (U.N., New York, 1985).

holdings or are landless laborers (8), and the number of people in these two categories is growing.

Ownership of agricultural land in Latin America tends to be concentrated in a relative handful of very large estates, or "latifundia." More than 80 percent of the agricultural land in seven South American countries (Brazil, Colombia, Ecuador, Peru, Suriname, Uruguay, and Venezuela) is in holdings of more than 50 hectares. Only 2 percent of the farmland in these countries is in holdings of less than five hectares, even though these small parcels constitute between 14 percent and 81 percent of all agricultural holdings, depending on the country (9).

In Asia, by contrast, about 7 percent of the farmland is in holdings of more than 50 hectares; about 45 percent of the land is in parcels of 5 hectares or less, which constitute 90 percent of all agricultural holdings (10). The FAO recently noted that the "high concentration of land holdings continued in many developing countries, especially in Latin America, and was associated with a high degree of rural poverty" (11).

In many regions of the Third World, the relative poverty of rural life and the concentration of employment opportunities in the urban centers have spurred migration from rural areas. Lured by the prospect of work and a better standard of living, rural migrants usually account for a large proportion of annual population growth in the cities (12), although the proportion varies considerably from one urban center to another.

The policies of Third World governments often give priority to urban areas, thereby encouraging rural to urban migration. Many governments set food prices at artificially low levels in an attempt to avoid social unrest in the cities. As well as reducing the cost of living in urban areas, this practice also reduces the profitability of agriculture. These factors work together to attract people to urban centers. Investments in infrastructure (e.g., roads, sewers) and other construction projects are usually concentrated in urban areas, as are government efforts to encourage industrial development.

## CONDITIONS AND TRENDS

### URBAN SETTLEMENTS IN THE THIRD WORLD

Over the past several decades, the most striking demographic feature of most of the 120 or so Third World nations has been the rapid population growth of urban areas. (See Figures 3.1A and 3.1B.) Rapid urbanization has been sustained by the combination of high rates of natural population increase (which are also responsible for the absolute population increases in rural areas) and rural-to-urban migration. The relative contribution of each to urban population growth varies, but in the majority of cities natural increases are the primary contributing factor. However, the two sources are intertwined, for a large proportion of those leaving the countryside are in their reproductive years and therefore may be partly responsible for the high rates of natural population increase in urban centers.

In many nations, urban population growth has not been uniform. Many, if not most, of the migrants from rural areas have been settling in one or two major cities, which are the hubs of economic activity. (See Box 3.2.)

The increasing concentration of people in urban centers has strained the capacity of most governments to provide basic services. Illegal settlements are common, and shortages of adequately paying jobs have created large pockets of urban poverty. In addition, levels of air and water pollution in the urban centers of the Third World often surpass those of the heavily industrialized regions of the First World. (See Box 3.3.) Almost without exception, city governments lack the personnel, resources, and power even to begin addressing these problems, and national governments tend to give low priority to the living conditions of the urban poor.

Although urbanization has been widespread in the Third World, its manifestations vary among countries, as do its causes. Moreover, generalizations about population movements mask recent changes that suggest a deceleration, and perhaps a reversal, of the concentrated growth of some dominant urban centers.

## Latin America

With 65.3 percent of its population living in cities in 1980, Latin America is the most urbanized of the three regions of the Third World. In 1985, four urban centers (Mexico City, Sao Paulo, Rio de Janeiro, and Buenos Aires) had populations exceeding 10 million, placing them among the world's 15 largest urban agglomerations. In all, one in four Latin Americans lives in a city with a population of at least 1 million.

Trends in Latin America exemplify the general relationship between levels of economic development and levels of urbanization found in most non-communist countries of the Third World. Between 1960 and 1982, the economies of Mexico, Colombia, and Brazil were among the most rapidly growing in Latin America; these countries also experienced the greatest increase—between 17 and 24 percent—in the proportion of the population living in urban areas. In contrast, economic growth was slow in Argentina, Uruguay, and Chile, and the pace of urbanization in these "southern cone" nations was modest during this 22-year period.

Other factors apart from economic activity may be contributing to the slowing of urbanization in the southern cone nations. With about 36 percent of the population living in cities with a million or more residents, Argentina, Chile, and Uruguay are among the most urbanized countries in the world. The highly concentrated populations in these countries, as well as in southern Brazil, result from events that began during the late 1800s and early 1900s, when the coasts of South America were the primary destinations of Europeans emigrating to the continent. The system of land tenure practiced in South America discouraged settlement in rural areas, as did the poor transportation network. Investment was concentrated along the coast, stimulating development of industry and its supporting infrastructure—ports, railroads, and urban services. Consequently, the populations of Buenos Aires and Rosario in Argentina, São Paulo and Rio de Janeiro in Brazil, and Montevideo in Uruguay swelled during the late 1800s and early

**Table 3.1 Distribution of the World's Population in Urban Areas by Region, 1960 and 1980**

| | Population (millions) | | Population In Urban Areas[a] (percent) | | Population in Cities with 100,000+ Residents (percent) | | Population in Cities with 1 million+ Residents (percent) | |
|---|---|---|---|---|---|---|---|---|
| | 1960 | 1980 | 1960 | 1980 | 1960 | 1980 | 1960 | 1980 |
| **Third World** | | | | | | | | |
| **Africa[b]** | | | **18.4** | **28.7** | | | | |
| Eastern Africa | 76.0 | 136.7 | 7.4 | 15.7 | 2.7 | 8.4 | 0.0 | 3.1 |
| Middle Africa | 34.9 | 54.6 | 18.2 | 34.4 | 7.1 | 18.7 | 0.0 | 9.7 |
| Northern Africa | 65.1 | 108.2 | 30.0 | 44.1 | 19.9 | 25.0 | 9.7 | 14.6 |
| Southern Africa | 20.8 | 32.8 | 42.2 | 49.2 | 22.8 | 23.0 | 6.3 | 13.0 |
| Western Africa | 80.7 | 143.8 | 13.4 | 22.8 | 5.6 | 15.8 | 0.0 | 5.5 |
| **Latin America[b]** | | | **49.3** | **65.3** | | | | |
| Caribbean | 20.4 | 29.5 | 38.7 | 52.3 | 19.1 | 28.8 | 7.1 | 15.6 |
| Central America and Mexico | 49.5 | 92.3 | 46.7 | 60.7 | 23.1 | 37.2 | 10.5 | 22.6 |
| Tropical South America | 116.1 | 198.0 | 46.1 | 65.8 | 24.7 | 41.5 | 14.3 | 26.2 |
| Southern Cone of South America | 30.7 | 42.3 | 72.7 | 82.4 | 46.7 | 54.2 | 32.7 | 35.9 |
| **Asia[b]** | | | **20.6** | **26.6** | | | | |
| China | 667.3 | 1,002.8 | 16.8 | 20.3 | 11.4 | 11.0 | 6.6 | 7.0 |
| Other East Asia (not including Japan) | 39.7 | 63.0 | 36.3 | 60.4 | 26.1 | 49.1 | 15.9 | 32.1 |
| South Asia | 864.5 | 1,408.2 | 18.3 | 25.4 | 9.7 | 15.9 | 4.0 | 8.2 |
| **Second World** | | | | | | | | |
| USSR | 214.3 | 265.5 | 48.8 | 63.2 | 25.6 | 36.2 | 6.0 | 14.0 |
| Eastern Europe | 116.7 | 134.9 | 44.5 | 56.3 | 19.5 | 26.4 | 8.0 | 10.4 |
| **First World** | | | | | | | | |
| Western Europe | 308.4 | 349.1 | 66.6 | 76.8 | 42.9 | 48.2 | 22.6 | 25.7 |
| North America | 198.7 | 251.9 | 69.9 | 73.8 | 49.5 | 56.3 | 28.7 | 34.7 |
| Japan | 94.1 | 116.7 | 62.5 | 76.2 | 30.5 | 45.6 | 21.7 | 27.0 |
| Australia and New Zealand | 12.7 | 17.9 | 79.8 | 85.8 | 54.8 | 69.1 | 31.7 | 47.0 |
| **World[c]** | **3,013.8** | **4,453.2** | **33.6** | **39.9** | **19.9** | **24.7** | **9.9** | **13.6** |

**Notes:**
a. Percentages in this column are not comparable due to use of different definitions of an urban population in each country.
b. Countries included in list of nations within each of the African, American, and Asian categories are the same as those used by the United Nations. Europe is divided into two categories: Eastern Europe (Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, and Yugoslavia) and Western Europe (all other countries).
c. Columns do not add to world totals since figures have been rounded and Melanesia and Micronesia were not included.
**Source:** United Nations (U.N.), *Estimates and Projections of Urban, Rural and City Populations, 1950-2025: The 1982 Assessment* (U.N., New York, 1985).

## Box 3.1 The Myth of International Urban Comparisons

Comparisons of national levels of urbanization (the proportion of the population living in cities or metropolitan areas) can be more deceiving than informative. For example, using its definition of "urban center," India is largely a rural nation, with only 24 percent of its own population residing in cities in 1981. In contrast, Peru, by its own definition, is much more urbanized than India. According to U.N. figures for 1985, about two thirds of the people in Peru live in cities. Were India to use Peru's definition of urban center—a settlement with at least 100 occupied dwellings—it would immediately become one of Asia's most urbanized nations. Using this definition would also significantly change urbanization statistics for Asia, because India is the continent's second most populous nation.

Obviously, India and Peru use vastly different criteria to classify cities, towns, and villages. According to the Indian government, an urban center has 5,000 or more inhabitants and, in addition to fulfilling other criteria, must have an adult male population that is employed predominantly in nonagricultural work. Most nations use population thresholds to identify urban centers, but these thresholds range from 100 to 50,000 inhabitants. Some nations do not even consider population size; but instead, identify urban centers as those settlements that have been designated as municipalities or centers of local government. As a result, comparisons among nations often contain little meaningful information.

An alternative to using national estimates of levels of urbanization is to compare percentages of total populations in cities with 100,000 plus or 1 million plus residents. Here the same criterion is used for each country, but comparisons made on this basis also pose problems. They often employ U.N. statistics (used for Table 3.1, main text), which may be extrapolated from older data because many nations have not taken censuses in recent years. These extrapolations rarely identify cities with population levels of 100,000 or 1 million since the last census. It is unlikely, for example, that China, the world's most populous nation, has only one city with a population of 100,000 to 249,999 residents, as reported by the United Nations in 1985. U.N. figures are often at odds with those reported by other sources. In addition, the U.N. data drawn from the report on which Table 3.1 is based greatly overestimate the proportion of many small nations' or territories' populations living in cities of 100,000 or more inhabitants. For these reasons the data on urban populations in this chapter supplement the U.N. data with national censuses and independent analyses where possible.

1900s, with rates of growth exceeding those experienced during recent decades.

A high proportion of Latin America's industry is concentrated in relatively few "core-regions." Three of the most prominent are the La Plata/Buenos Aires/Campana/Zarate/San Nicholas/Rosario/San Lorenzo region in Argentina, the triangle of Rio de Janeiro/Sao Paulo/Belo Horizonte in Brazil, and Mexico City/Toluca/Cuernavaca/Puebla/Queretaro in Mexico. Although the general trend in Latin America's large cities has been for much of the new and expanding industry to be within or near city centers, in recent years industrial and commercial employment has grown more rapidly outside the inner cities. Some central cities have been growing more slowly than suburban rings (or even losing population), and some cities beyond the commuting range of the largest centers have grown more quickly than the metropolitan areas.

The central city, or Federal District, of Buenos Aires, for example, lost population during the 1970s, while the rest of the Greater Buenos Aires Metropolitan Area experienced a population increase of 30 percent. Overall, however, the metropolitan area's share of Argentina's population increased only 0.1 percent during the 1970s, compared with 2 percent during the previous decade. Population growth is slowing in Peru's Lima-Callao area as well. With an estimated 4.4 million inhabitants in 1981, Lima-Callao was among the slowest-growing urban centers with 50,000 or more residents, according to figures for 1972 to 1981.

The rate of population growth in the central city of Sao Paulo has been eclipsed by the increase in the surrounding metropolitan area and, more recently, in cities outside Greater Sao Paulo (13). Comparable trends are evident in the Mexico City Metropolitan Area. Although its population continues to increase, the Federal District has declined in terms of its share of the total population of the Mexico City Metropolitan Area. Relative declines in the Federal District's population, as well as in its share of the metropolitan area's industrial and commercial activity, are expected to continue (14). Moreover, various cities near, but not within, the metropolitan area grew more rapidly during the 1970s than did the metropolitan area itself. Although Mexico City continues to be the primary target of rural-to-urban migration in Mexico, evidence suggests that its attractive power has diminished somewhat. Between 1940 and 1950, 49 percent of all migrants moved to Mexico City; during the next decade, the figure dropped to 42 percent (15).

Contrasting with the pattern of urban growth in the rest of Latin America is the situation in Cuba. Since the mid-1960s the proportion of the urban population living in Havana, the capital and much the largest city, has declined. This decline is largely the result of both the agrarian reform implemented after the revolution in the late 1950s and government efforts to stimulate economic and social development outside Havana. Postponement of new housing and infrastructure investments in Havana has also contributed to the decline of the city's economic and demographic dominance (16).

### Asia

Aggregate statistics always mask diversity—a limitation to bear in mind when considering population distribution in Asia, where over two thirds of the population lives in two countries: China and India. Overall, Asia is less urbanized than Latin America, but it does contain nine urban centers with 5 million or more residents: three in China, three in India, and one each in South Korea, Indonesia, and the Philippines.

During the 1960s and 1970s, urbanization proceeded most rapidly in the resource-rich and more economically advanced nations of Asia. Saudi Arabia, South Korea, and Iran underwent the most dramatic transformations; the urban proportion of their total populations increased a third or more between 1960 and 1982. In Saudi Arabia, much of this change is attributed to immigration, including a large influx of temporary workers. In Bangladesh, Nepal, Burma, India, and other poor Asian nations, the pace of urbanization was much slower, even though some of these countries, including Bangladesh and Pakistan, registered substantial increases in manufacturing output during the last two decades.

A mix of demographic changes is occurring in India, although it is not readily apparent in national data. Among India's 12 cities with a million or more inhabitants as of 1981, Lucknow, Kanpur, and Calcutta appear to be experiencing net out-migration, but Bangalore has been growing rapidly. Patterns of urban population growth in India, unlike those elsewhere in the Third World, seem to be less tied to the large urban centers. For example, a demographic study of cities in a relatively rich, urbanized region and cities in a relatively poor, largely rural region found no clear correlation between the size of urban centers and their rates of growth (17). During the 1970s, India's fastest growing cities were those with a population of less than 500,000 in 1971. Many of these cities, which tended to be state capitals, mining centers, or single industry towns, were located far from India's most densely populated regions. Other signs of deconcentrating urban population were evident in such large metropolitan areas as Bombay, Calcutta, and Hyderabad. Cities outside, but near, these metropolitan areas have been growing more rapidly than the central cities (18).

In China, population movements are greatly influenced by the government. Between 1961 and 1976, for example, the country underwent government-imposed de-urbanization, through forced resettlement and strict control of access to jobs, housing, and food. During this period, peasants were recruited to work in industry, but their dependents were not allowed to live with them in their city of employment, a practice that was used by colonial governments in sub-Saharan Africa. Since 1977, however, China's urban population has grown rapidly, with rural-to-urban migration playing a larger role than natural increase. The Chinese government has officially sanctioned the return to urban areas of the millions of people who had been removed to the countryside during the previous period (19).

## Africa

Africa has long been the least urbanized of the world's continents, despite a rich and varied (although poorly documented and often poorly understood) urban history that stretches back centuries in many nations. Its largest city is Cairo in Egypt, which, according to some sources, had more than 10 million inhabitants in 1985; Lagos in Nigeria is the second largest urban center, with an estimated population of 5 million in 1985 (20).

In the majority of sub-Saharan nations, at least 75 percent of the population lived in rural areas in 1980, and

### Box 3.2 City Primacy within National Economies

**Abidjan (Ivory Coast):** In 1978, some 70 percent of all economic and commercial transactions were said to take place in Abidjan, which contained around 15 percent of the national population.

**Bangkok (Thailand):** The metropolitan area contained 86 percent of gross national product (GNP) in banking, insurance, and real estate, 74 percent of manufacturing, 61 percent of government expenditures in public administration and defense, and one third of national gross domestic product (GDP) in the early seventies. At that time, it had 10 percent of the national population.

**Lagos (Nigeria):** In 1981, the metropolitan area handled over 40 percent of the nation's external trade, accounted for over 57 percent of total value added in manufacturing, and contained over 40 percent of highly skilled manpower. It contains about 5 percent of the national population.

**Lima (Peru):** The metropolitan area accounts for 43 percent of GDP, four fifths of bank credit and consumer goods production, and more than 90 percent of capital goods production in Peru. It contained about 27 percent of the national population in 1981.

**Managua (Nicaragua):** A report in 1983 suggests that enterprises in Managua account for 38 percent of the nation's GDP. It contains about 25 percent of the national population.

**Manila (Philippines):** The metropolitan area produces one third of the nation's GNP, handles 70 percent of all imports, and contains 60 percent of all manufacturing establishments. In 1981, it contained about 13 percent of the national population.

**Mexico City (Mexico):** In 1970, it contained 30 percent of total employment in manufacturing, 28 percent of employment in commerce, 38 percent of employment in services, 69 percent of employment in national government, 62 percent of national investment in higher education, and 80 percent of research activities. In 1965, it contained 44 percent of national bank deposits and 61 percent of national credits. In 1970, it contained about 24 percent of the national population.

**Nairobi (Kenya):** In 1975, it contained 57 percent of all Kenya's manufacturing employment and, in 1974, 67 percent of its industrial plants. By 1975, Nairobi and its industrial satellite, Thika, contained 61 percent of all industrial wage employment. In 1979, Nairobi contained 5 percent of the national population.

**Port au Prince (Haiti):** Approximately 40 percent of the national income is produced within Port au Prince. It monopolizes all urban economic activities. The centralized political and administrative system and development policies geared to the manufacturing sector have contributed to this situation. Only some 14 percent of the national population lives there.

**Rangoon (Burma):** Located at the center of the national transport and communications network, Rangoon is the economic, political, and administrative heart of Burma. It is the dominant tertiary service center, and virtually all the import and export trade passes through its port. More than half the national manufacturing industry is said to be located there. In 1981, it contained 6 percent of the national population.

**São Paulo (Brazil):** In 1980, Greater São Paulo contributed over 40 percent of Brazil's industrial value-added manufacturing and one quarter of net national product. In that same year, it contained about one tenth of the national population.

**Source:** Adapted from Table 2 in J.E. Hardoy and D. Satterthwaite, "Government Policies and Small and Intermediate Urban Centres," in *Small and Intermediate Urban Centres: Their Role in Regional and National Development in the Third World*, J.E. Hardoy and D. Satterthwaite, Eds. (Hodder and Stoughton, London, 1986).

most were working in agriculture. Despite their largely rural character, many of these nations offer the most striking examples of urbanization in recent decades. For example, since 1950, the populations of Nairobi in Kenya, Abidjan in the Ivory Coast, and Dar es Salaam in Tanzania have increased more than sixfold (21). During the same period, the population of Lagos grew more than sixteenfold (22); and the number of people living in Nouakchott in Mauritania is estimated at more than 40 times the 1965 population (23). For most of these cities and others that have experienced marked population increases, migrants account for most of the rapid growth since the 1950s, even though sub-Saharan Africa has some of the world's highest rates of natural increase.

This rapid growth in urban population has often occurred in spite of economic stagnation. For example, Chad, Zaire, the Central African Republic, and Ghana experienced little or no economic growth during the 1960s and 1970s, but the proportion of their populations living in urban areas increased at least 12 percent between 1960 and 1982. This population growth was partly a response to the removal of population restrictions imposed by former colonial governments and partly to the building of the necessary institutional structure after independence was gained. By focusing on cities, government-funded efforts to spur industrial development have also contributed to rapid urbanization.

Such factors are evident in Tanzania's urban population growth. In 1952, 27 percent of the inhabitants of the colonial capital, Dar es Salaam, were non-African, and among the African population, men outnumbered women by a ratio of 1.5:1. This imbalance was the result of colonial policies that strongly discouraged women and children from living with their husbands and fathers in urban centers. Tanzania's independence triggered a large wave of migration to cities, with women comprising a significant part of the influx. By 1967, the imbalance between the sexes had been reduced to a ratio of 1.2:1 (24).

Trends in the country of South Africa stand out as exceptions to those in the rest of sub-Saharan Africa, as well as to those in the northern part of the continent. South Africa's system of apartheid accounts for this difference. There the majority of the population is denied basic economic, political, and social rights on the basis of race. As a result, most South African residents are prevented from moving from areas of high unemployment and the predominantly rural "homelands" to which many have been forcibly relocated.

Patterns of population movement in northern Africa are more akin to changes taking place in Asia and Latin America. For instance, between 1970 and 1982, Algeria, Tunisia, Libya, and Morocco had rates of growth in gross domestic product and manufacturing output that were among the highest in Africa. These countries were also among the leaders in terms of increases in the proportion of the national population living in urban areas. In Libya, for example, this proportion increased 35 percent.

From the perspective of the entire continent, little can be concluded about trends in the growth rates of cities in different population categories. The data base is too poor for such broad trends to be discernible, but some evidence suggests that the largest cities within some nations may be attracting a lower proportion of new economic investment. During the decade 1969–79, Kenya's two largest cities, Nairobi and Mombasa, had slower rates of population increase than any of the other 16 urban centers that had more than 20,000 residents in 1979. Recent reports also suggest that Cairo's population growth has begun to slow considerably (25). With the scanty evidence available, however, it is not possible to determine whether parts of Africa are moving toward deconcentration of the urban population.

## Box 3.3 The Environmental Problems of Cities

The legacy of death and injury that resulted from the chemical leak in Bhopal, India, in 1984 has focused global attention on the environmental problems of Third World cities. More serious than tragedies such as Bhopal, however, are the environmental insults suffered daily by city residents. In many cities, high concentrations of heavy metals have been found in drinking water supplies, and a growing number of case studies have documented the high frequency of pollution-related illnesses. Because of the lack of enviromental regulations or the lack of enforcement, such problems are not limited to cities with high concentrations of industry. Communities with only a few factories have had their water supplies polluted as a result of careless emissions, a problem that is often compounded by the inadequacy or complete lack of local sewage and drainage systems. The toll of such environmental damage usually falls disproportionately on the urban poor, who tend to live in the most polluted sections of cities and who, because of the lack of basic services, often must draw their drinking water from polluted rivers.

Although it may originate in cities, environmental pollution and the damage it inflicts are not confined to city boundaries. Air pollution from heavy concentrations of industry has caused serious crop damage many miles away from the sources of pollutants, and disposal of wastes into local waters has destroyed coastal and river fisheries. In addition, the lack of effective planning has allowed urban developments to consume productive farmland, reducing the agricultural base for satisfying national food needs and displacing agricultural workers who then must move to cities to find work. Pollution, urban sprawl, and the growing urban demand for raw materials such as fuelwood have aggravated problems of deforestation and destruction of the natural landscape, resulting in environmental losses that will be felt for years to come.

Some of the serious enviromental problems found in the cities of the First and Second Worlds are the result of past carelessness and inadequate environmental controls. Although First World cities usually have the necessary infrastructure, the deterioration of this infrastructure through aging is a frequent problem. Cities cannot always afford the necessary investments to repair sewage systems, roads, etc., particularly if the city tax base has been declining as businesses and richer households move out. As in the Third World, environmental problems that originate in the cities of the First and Second Worlds reach far beyond urban boundaries. For example, most sulfur and nitrogen oxides originate from coal-fired power plants, smelters, and automobiles in urban areas, although the harmful effects of acid deposition are felt primarily in rural areas.

## URBAN SETTLEMENTS IN THE SECOND WORLD

The nine nations of the Second World comprise 9 percent of the world population, with the Soviet Union accounting for two thirds of the total population and 95 percent of the total land area. These nations, which are characterized by their centrally planned economies and the political and economic interdependence that has developed under the influence of the Soviet Union, contain no urban centers with a population of 10 million or more. Population distribution is dictated largely by government priorities and programs. The scope of government influence varies among nations, however, as do other factors affecting settlement patterns, including the type and level of development of the industrial, agricultural, and service sectors.

While most Second World nations urbanized rapidly during the 1960s and 1970s, the rate of urban population growth was slow by world standards, even though economic growth is believed to have been relatively high in most countries. As in the First World, low rates of natural increase helped keep growth in urban populations well below the norm for Africa, Asia, and Latin America.

The limited data available suggest considerable economic restructuring during the past two decades. Most countries experienced significant shifts in the relative importance of agriculture, industry, and services in terms of these sectors' contributions to gross domestic product and job creation. The proportion of the labor force working in agriculture declined substantially in most countries, and the proportion working in industry increased substantially. An exception is Albania, the only Second World country in which agriculture is the primary employer. According to estimates for 1981, 61 percent of Albania's labor force was engaged in agricultural work. Yugoslavia represents another exception because of the large proportion of the work force employed in the service sector. In 1980, 36 percent of Yugoslavia's workers had service-related jobs, and 35 percent were employed in industry, according to estimates. In all other Second World nations, the industrial sector's share of national employment was larger than that of the service sector. This distribution of employment contrasts with the First World and some of the richer nations of the Third World, where most jobs are in the service sector. Finally, East Germany has been relatively unaffected by the economic trends that have characterized much of the Second World during recent decades. In 1960, it was the most urbanized, and one of the most industrialized Second World nations, and since then it has experienced smaller changes than most other countries in its economic structure and employment pattern.

The prominence of industry in the Second World is largely a reflection of central economic planning. During the 1950s (and before then in the Soviet Union), development of industry—especially heavy industry—was a high priority. Location of new factories was usually guided by economic logic, which considers such factors as proximity to raw materials and energy sources. Other factors—social, political, and military—also influenced location decisions, however. For example, some industrial development was aimed at reducing disparities between the more industrialized northern nations and their less developed Balkan counterparts, and other development was intended to increase employment opportunities in the poorer, less-urbanized regions of the Second World.

The fact that most or all investment is controlled by the state implies that the state has the means to determine both the form and location of urban development. The relatively low proportion of the Second World population living in cities with 1 million or more inhabitants is striking, considering levels of industrial development, and it may reflect the aim to control urban population growth. (See Figures 3.2A and 3.2B.) The state's demographic influence is particularly apparent in the Soviet Union's ambitious "new town" program. Between 1926 and 1963, more than 800 new towns and cities were built, one third of them on new sites. As of 1980, nearly 30 percent of the Soviet Union's urban population lived in new towns, compared with about 6 percent in Great Britain, which has one of the First World's largest new town programs. In Eastern Europe some 60 new towns have been constructed, but only about 3 percent of the Second World's urban population lives in them.

Urban and economic planning notwithstanding, industrial development and population distribution in the Second World are less uniform than government plans and policies might suggest. Ambitious planning goals to slow or halt the population growth of certain large cities, for example, have not been met. Industrial ministries, agencies, and enterprises have frequently been at odds with territorial or spatial-planning goals, and their interests have usually prevailed. Moreover, the social benefits of steering industry to poor regions have often fallen short of expectations, and the costs of development are often higher than anticipated. As a result, industry tends to remain concentrated in the Second World's traditional industrial heartlands.

From the perspective of the Second World's urban centers, perhaps the two most pressing problems are inadequate housing and pollution. Some nations continue to feel the devastating effects of World War II. Yugoslavia, for example, lost three quarters of its housing stock during the war. Urban population growth and decreasing household size have aggravated housing shortages, but some governments have given this problem a low priority. From the mid-1960s to the late 1970s, governments did increase their support for housing construction, bringing some relief, but they decreased support during the 1980s. Serious problems remain and are likely to worsen if this decrease in government support persists. In all nations except the Soviet Union and Romania, governments have taken steps to counter inefficiency in public housing programs by increasing support for construction of private and cooperative housing. These governments also have encouraged transferring housing ownership to tenants (26).

The Second World's industrial centers also suffer from serious environmental problems, especially in East Germany, Poland, and Czechoslovakia. In some areas, levels



from economic restructuring to lifestyle choices, whose relative significance is difficult to establish. It is certain,

high average incomes and other favorable economic and social indicators (31).

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## Box 4.2 Land, Food, and People

The concept of "carrying capacity"—the number of people that a given amount of land can support—has fascinated scientists, economists and philosophers for centuries. Ever since Thomas Malthus postulated in 1812 that linear increases in food production and geometric increases in population growth would inevitably lead to starvation, there has been debate about the Earth's carrying capacity.

Carrying capacity is still not adequately enough defined to serve as a policy tool, nor are the available data nearly comprehensive or accurate enough to calculate the number of people the planet could hypothetically support. In 1984, however, the U.N. Food and Agriculture Organization (FAO) published "Potential Population Supporting Capacities of Lands in the Developing World," the most sophisticated attempt yet to estimate the carrying capacities of 117 developing nations (1).

The first pillar of the study is a series of 1:5,000,000 scale soil maps of the world created over a 20-year period by FAO and the United Nations Education, Scientific and Cultural Organization (UNESCO). The maps classify soils, terrain, and bedrock for the entire world by translating national mapping systems into an international framework.

The second pillar is the climate information from FAO's Agroecological Zone Project, which mapped crucial climate data for the world, including rainfall, radiation, temperature, and length of growing period. Superimposing the two maps produced a mosaic of thousands of units—or cells—with distinctive land and climate characteristics.

The researchers then used a complex computer program to determine the particular food crop that would provide the greatest amount of protein and calories for each land/climate unit, thus yielding a rough estimate of the maximum food-producing (calorie-producing) capability of each nation. The theoretical carrying capacity of each country was then calculated by dividing each nation's total potential calorie production by the FAO's minimum daily calorie requirement.

Because agricultural output depends so heavily on technological inputs, three scenarios were defined to fine-tune the results. The low level of optimization assumed that no fertilizer, biocides, or improved crop varieties were used, that no land conservation measures were practiced, and that traditional crop-mix patterns would be followed. The high level of optimization assumed full use of biocides, fertilizer, and conservation measures and the optimum crop variety throughout the entire cell. The intermediate level assumed basic use of biocides and fertilizer, simple land conservation practices, some improved crop varieties, and the optimum crop on half the land of each cell.

The results were expressed as a ratio by comparing the theoretical population that can be adequately fed first to the actual population in 1975, and then to the projected population in 2000. (See Table 1.)

For the 117 countries taken as a whole, the study revealed that the land base could provide food for twice the actual 1975 aggregate population, assuming the low level of farming inputs. As the level of inputs increased, the carrying capacity rose dramatically. On the other hand, projections for the year 2000 showed a significantly tighter situation at all input levels because of the large growth in population.

Overall, the developing world appears to be in tolerably good shape, able to support twice its 1975 poulation even at low input levels. On a country-by-country basis, however, the numbers are disturbing. At the 1975 low input level, fully 55 countries were "critical" (i.e., they had a ratio of less than 1:1 and were not able to support even their existing population). By 2000, 64 countries are projected to be critical, including the entire region of southwest Asia.

In fact, the model is overly optimistic. The study assumed that all potentially cultivable land is used to grow nothing but staple food crops or to provide pasture for livestock, and that the produce is divided equally among social groups to provide a basic calorie requirement. In reality, land would need to be set aside for forestry, vegetables, fibers, non-food cash crops and other uses (although the model did account for land lost to roads, cities, mining, factories, and parks), which would substantially reduce potential production. Moreover, the realistic per capita consumption would be considerably lower because of sharp inequities in distribution and other factors. Conversely, the study did not take into account the role of fish in the human diet, which would brighten the picture measurably, since 60 percent of the people in the developing world derive 40 percent or more of their protein from fish (2). Taking these variables into account, the authors suggest that all findings of the study should be reduced by about 30 percent to account for considerations too complex to model.

The single most unrealistic assumption of the study—and the one that cuts to the heart of the controversy over carrying capacity—is the artifical premise that there is no trade between countries. That assumption places Singapore and Saudi Arabia, for instance, in artificially bad shape, unable to feed their populations under any conceivable situation. In fact, of course, both are wealthy in resources other than productive land, and are able to trade resources or manufactured goods for food. Critics contend that any study of nation-by-nation carrying capacity is fatally flawed because land or climate is not necessarily a limiting factor; through the medium of money, all resources, including such non-physical items as knowledge and service, are theoretically exchangeable for food.

Nevertheless, the FAO study presents a compelling and sobering portrait of the agricultural capabilities of an increasingly populated developing world, many parts of which need to think in terms of self-sufficiency because they lack the financial resources to purchase food abroad.

### References and Notes

1. U.N. Food and Agriculture Organization (FAO), *Potential Population Supporting Capacities of Lands in the Developing World*; a short summary of the study was published under the title *Land, Food and People* (FAO, Rome, 1984).
2. U.N. Food and Agricultural Organization (FAO), *The State of Food and Agriculture* (FAO, Rome, 1985), p. 63.

**Table 1 Potential Population-Supporting Capacities Divided by 1975 and 2000 Populations**

| Input Level | Africa | SW Asia | South America | Central America | SE Asia | Average |
|---|---|---|---|---|---|---|
| **1975 Ratios** | | | | | | |
| Low | 3.0 | 0.8 | 5.9 | 1.6 | 1.1 | 2.0 |
| Intermediate | 11.6 | 1.3 | 23.9 | 4.2 | 3.0 | 6.9 |
| High | 33.9 | 2.0 | 57.2 | 11.5 | 5.1 | 16.6 |
| **2000 Ratios** | | | | | | |
| Low | 1.6 | 0.7 | 3.5 | 1.4 | 1.3 | 1.6 |
| Intermediate | 5.8 | 0.9 | 13.3 | 2.6 | 2.3 | 4.2 |
| High | 16.5 | 1.2 | 31.5 | 6.0 | 3.3 | 9.3 |

**Source:** U.N. Food and Agriculture Organization (FAO), *Land, Food, and People* (FAO, Rome, 1984).

Africa are unable to attain even 1,000 kilograms per hectare. (See Table 4.4.)

In the developing world, the agricultural success stories of the past several decades are South and East Asia, particularly India and China. The principal beneficiaries of the green revolution, these regions used new crop varieties such as dwarf rice, semi-dwarf wheat, and opaque-two type maize to consistently propel production ahead of population gain. By the year 2000, the U.N. Food and Agriculture Organization (FAO) projects that per person calorie consumption in the Far East will have improved by almost 9 percent over 1974–76 levels (16). Nevertheless,

**Table 4.2 Total and Per Capita Cropland and Resources, 1971–75 and 2000**

| Region | Cropland and Potential Cropland (million hectares) | Cropland[a] (million hectares) 1971–75 | 2000 (projected) | Cropland Per Capita (hectares) 1971–75 | 2000 (projected) |
|---|---|---|---|---|---|
| **Industrial Market Economies (Total)** | 1,023.3 | 400.3 | 399.1 | 0.55 | 0.46 |
| United States | 540.5 | 200.5 | 208.0 | 0.95 | 0.84 |
| Western Europe | 225.1 | 90.1 | 87.0 | 0.26 | 0.22 |
| Japan | 13.7 | 5.7 | 5.1 | 0.05 | 0.04 |
| Other major exporters[b] | 244.0 | 104.0 | 99.0 | 1.58 | 0.94 |
| **Centrally Planned Economies (Total)** | 884.4 | 414.5 | 420.0[c] | 0.35 | 0.26 |
| Eastern Europe | 114.4 | 54.4 | X | 0.43 | 0.36 |
| USSR | 552.5 | 232.5 | X | 0.93 | 0.73 |
| China | 217.5 | 127.5 | X | 0.16 | 0.11 |
| **Less Developed Countries (Total)** | 2,232.0 | 662.0 | 723.5 | 0.35 | 0.19 |
| Latin America | 611.5 | 136.5 | 165.0 | 0.47 | 0.28 |
| North Africa/Middle East | 221.5 | 91.5 | 91.0 | 0.47 | 0.22 |
| Other African LDCs | 760.5 | 160.5 | 182.5 | 0.62 | 0.32 |
| South Asia | 437.5 | 207.5 | 207.0 | 0.26 | 0.13 |
| Southeast Asia | 99.9 | 34.9 | 41.0 | 0.35 | 0.20 |
| East Asia | 101.1 | 31.1 | 37.0 | 0.13 | 0.08 |
| **World (Total)** | **4,139.7** | **1,476.8** | **1,538.6** | **0.39** | **0.25** |

X = not available
**Notes:**
a. Cropland includes land under permanent and temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens (including cultivation under glass), and land temporarily fallow or lying idle. This category is called "arable and permanent cropland" by FAO.
b. Canada, South Africa, Australia, and Argentina.
c. Cropland in centrally planned countries is thought to be near maximum. Growth in land used outside the agricultural sector approximately balances cropland area increase.
**Sources:**
1. U.S. Council on Environmental Quality, *The Global 2000 Report to the President*, p. 97 and p. 99.
2. U.S. Geological Survey (USGS), *Supporting Data for Environmental Trends* (USGS, Washington, D.C., 1983), p. 232.

with a massive population and widespread poverty, South and East Asia continue to be the least well-nourished parts of the world both in absolute numbers and in percentage of their populations. (See Table 4.1.) at present, well over 200 million Asians are seriously undernourished; by the year 2000, even though a larger percentage will be better fed, the number chronically short of calories is projected to reach 450 million (17).

Had it not been for the green revolution coupled with declining rates of population growth, the food situation in Asia would now be catastrophic.

## Irrigation

The high-yielding plant varieties of the green revolution have certain specialized needs, including large quantities of water, fertilizer, and pesticides. Part of the Asian success story was the continent's ability to provide these inputs, particularly through irrigation.

Of the world's 212.9 million hectares of irrigated cropland in 1981, Asia (outside the Middle East) had 120.1 million hectares, or 56 percent (18). Use of irrigation spread rapidly throughout the world in the 1970s—2.3 percent per year—and by 1994 over a quarter of a billion hectares are projected to be free from dependence upon the vagaries of rainfall. (See Table 4.5.)

Through a beneficial confluence of geography, hydrology, climate, financial investment, and managerial ability, India has become a showcase for the power of irrigation. In the period 1950–83, the nation's cereal production increased from about 55 million to 140 million tons per year, and over 50 percent of that increase is attributable to irrigation (19).

**Table 4.3 Grain Yield Per Hectare, by Region, 1950–52 and 1980–82**

| Region | Average Yield (kilograms) 1950–52 | 1980–82 | Change (percent) |
|---|---|---|---|
| North America | 1,646 | 3,757 | 128 |
| Western Europe | 1,733 | 3,843 | 122 |
| East Asia | 1,419 | 2,973 | 109 |
| Eastern Europe | 931 | 1,819 | 95 |
| South Asia | 825 | 1,450 | 76 |
| South America | 1,217 | 1,854 | 52 |
| Africa | 757 | 1,044 | 38 |
| Australia[a] | 1,100 | 1,301 | 18 |
| **World** | **1,186** | **2,247** | **89** |

**Note:** a. Data are for 1981-83 to avoid trend distortion.
**Sources:**
1. U.S. Department of Agriculture (USDA), Economic Research Service, *World Indices of Agricultural and Food Production, 1974–83* (USDA, Washington, D.C., 1984).
2. U.S. Department of Agriculture (USDA), Economic Research Service, unpublished data.

**Table 4.4 Grain Yield in Selected Countries, 1974–76 and 1981–83**

| | Average Yield (kilograms/hectare/year) 1974–76 | 1981–83 |
|---|---|---|
| Netherlands | 4,771 | 6,357 |
| Japan | 5,620 | 5,278 |
| Korea, Republic of | 4,140 | 5,183 |
| Germany, Federal Republic of | 3,973 | 4,623 |
| Egypt | 3,921 | 4,254 |
| United States | 3,339 | 4,075 |
| Korea, Democratic Republic of | 3,590 | 4,010 |
| German Democratic Republic | 3,575 | 3,834 |
| China | 2,479 | 3,399 |
| Indonesia | 2,338 | 3,165 |
| Canada | 2,027 | 2,355 |
| Argentina | 1,971 | 2,353 |
| Mexico | 1,698 | 2,273 |
| Bangladesh | 1,771 | 1,993 |
| Thailand | 1,882 | 1,960 |
| South Africa | 1,403 | 1,608 |
| Brazil | 1,420 | 1,591 |
| USSR | 1,466 | 1,448 |
| India | 1,179 | 1,435 |
| Australia | 1,384 | 1,298 |
| Ethiopia | 966 | 1,280 |
| Portugal | 1,118 | 962 |
| Nigeria | 662 | 696 |
| Sudan | 645 | 603 |
| Niger | 395 | 408 |

**Source:** U.N. Food and Agriculture Organization (FAO), *Production Yearbook 1983*, Vol. 37 (FAO, Rome, 1984).

**Table 4.5 Land Under Irrigation, 1970–94**

| Region | Million Hectares[a] 1970 | 1981 | 1994 | Average Annual Change (percent) 1970–81 | 1981–94 |
|---|---|---|---|---|---|
| North Africa/Middle East | 16.0 | 18.3 | 20.6 | 1.2 | 0.9 |
| Sub-Saharan Africa | 3.4 | 4.5 | 5.2 | 2.7 | 1.1 |
| European Economic Community | 4.7 | 6.1 | 8.6 | 2.4 | 2.7 |
| Other Western Europe | 3.1 | 3.9 | 4.6 | 2.1 | 1.2 |
| USSR | 11.1 | 18.0 | 24.7 | 4.5 | 2.5 |
| Eastern Europe | 2.7 | 4.7 | 6.0 | 5.0 | 1.9 |
| South Asia | 45.0 | 56.8 | 69.9 | 2.1 | 1.6 |
| East Asia | 12.6 | 15.4 | 17.0 | 1.8 | 0.8 |
| Asian Centrally Planned Economies | 39.7 | 47.9 | 54.3 | 1.7 | 1.0 |
| Oceania | 1.6 | 1.8 | 1.9 | 1.2 | 0.5 |
| Latin America | 10.2 | 14.4 | 18.4 | 3.2 | 1.9 |
| North America | 16.4 | 21.1 | 26.3 | 2.3 | 1.7 |
| **World** | **166.5** | **212.9** | **257.5** | **2.3** | **1.5** |

**Note:** a. Estimates vary widely. Compare these figures with Chapter 8, "Freshwater," Table 8.6.
**Source:** Adapted from Winrock International, 1985, Reference 8.

Although irrigation is perhaps the single most effective way to increase yields of most crops (see Table 4.6), it has serious drawbacks—economic as well as environmental. Irrigation systems are very expensive to construct, with typical costs running $1,000–2,000 per hectare but ranging as high as $20,000 per hectare (20). They also require constant maintenance to prevent enormous rates of leakage, and close, sophisticated management. Over-irrigation leading to waterlogged soil and excessive salinity is endemic. Since the Mesopotamians, history is replete with examples of agricultural systems that have failed because of faulty irrigation. Often the failure is permanent, leaving once productive farmland as wasteland. Salinization is currently a serious problem in both developed and developing countries, from the richest to the poorest. Worldwide, salinization alone may be causing as much land to be abandoned as is currently being brought under irrigation (21).

In India, where 40 million hectares were irrigated in 1982 (half of them by surface systems, half by wells) more than 7 million hectares were affected by salinity and alkalinity (22). Waterlogged areas are counted among those lands defined as "water-eroded," a staggering 73.6 million hectares out of India's total agricultural area of 143 million hectares. The total amount of land degraded by salinity and waterlogging is not precisely known but is estimated to be about half of the total land irrigated by surface systems (23).

Obviously, irrigation requires water. Egypt, Israel, and California may have been able to make relatively small areas of desert bloom, but the vast deserts of the developing world are essentially unirrigable.

**Table 4.6 Extent of Irrigated Lands and Their Use for Food Production, in Selected Countries**

| Country | Percent of Cultivated Land Under Irrigation | Percent of Total Food Production From Irrigated Land |
|---|---|---|
| India | 30 | 55 |
| Pakistan | 65 | 80 |
| China | 50 | 70 |
| Indonesia | 40 | 50 |
| Chile | 35 | 55 |
| Peru | 35 | 55 |
| Mexico | 30 | X |

X = not available
**Source:** W.R. Rangeley, 1985, Reference 19.

Unfortunately, the continent that needs the benefit of irrigation the most, Africa, has the lowest potential for it. Except in South Africa and along the Nile River, a variety of factors conspires against irrigation: its great expense, unfavorable topography and rainfall patterns, and insufficient numbers of trained managers. Also, the climate in much of the continent promotes the growth of disease carrying organisms, which flourish in the standing water of irrigation reservoirs and ditches. Only about 2 percent of Africa's arable land is now irrigated (24).

## Fertilizer

After land and water, fertilizer is probably the most important factor in crop output; its increased use was responsible for about 55 percent of the increase in yields in developing countries between 1965 and 1976 (25). Fertilizer use correlates directly with output. By 1974–76, world fertilizer use had reached an aggregate level of 60 kilograms per hectare of arable land (ranging from a low of only 1 kilogram per hectare in several African countries to a high of over 700 in the Netherlands). (See Part IV, Chapter 5, "Food and Agriculture.")

Nations that use fertilizer heavily are not relying solely upon the natural materials at hand—crop residues, biomass, and animal waste. They are also producing or purchasing expensive synthetic petroleum-based fertilizer that is beyond the financial means of many developing nations. However, there are some low-cost strategies that even poor nations can adopt to increase their fertilizer supply. For instance, confinement of animals instead of wide-ranging grazing makes the collection of manure practicable. Also, the substitution of small biogas generators for the direct burning of manure—as the Chinese have done—provides energy for cooking and other uses while leaving a nutrient-rich slurry for crop enhancement.

Except for China, fertilizer use in the developing world remains much lower than in industralized countries, but it did increase during the 1970s. The developed countries at the beginning of that decade used 5.5 times more fertilizer per hectare than the low-income economies, but by 1980 that ratio had been reduced to 2.2:1 (26).

## Pesticides

World pesticide sales grew from $8.1 billion in 1972 to $12.8 billion in 1983 (in 1983 dollars), with the most rapid growth occurring in the developing countries. The developed nations now use about 85 percent of all pesticides, down from 92 percent at the beginning of the decade (27). Pesticides are a vital element of the high-input, high-productivity agriculture that set new production records as it swept across Asia, parts of Latin America and other developing regions. However, as their use increases, pesticides' severe health and environmental impacts are becoming ever more evident.

Unfortunately, a significant fraction of the pesticides used in the Third World are those that have been banned for health and environmental reasons in some or all of the developed nations, DDT being the chief example. According to an estimate by the U.S. General Accounting Office, 29 percent of U.S. pesticide exports were not registered for use in the United States; of these, 20 percent had been canceled or suspended by the government as unsafe to health or the environment (28).

Despite more than three decades of experience in using pesticides, astonishingly little is known about their effects on human health. Reliable data on poisonings and deaths do not exist. The most comprehensive study, a 1973 effort by the World Health Organization (WHO), concluded that there are perhaps 490,000 cases of poisoning annually (with an uncertainty making the range 250,000 to 1,435,000) (29). The WHO committee estimated that the death rate from poisonings is 1 percent if antidotal facilities are available, but a cursory examination of selected country reports shows an actual death-to-poisoning ratio greater than one in ten. Though spotty, these findings demand concern. (See Table 4.7.)

From a purely environmental perspective, the accelerating rate at which insect, weed, and other pest species are becoming resistant to pesticides may be even more serious. Between 1970 and 1980, the number of arthropod species (insects, arachnids, and crustaceans) exhibiting reistance almost doubled, while for certain chemical groups such as the carbamates, the number of resistant species increased as much as 17-fold. (See Figure 4.1.) The total number of cases of arthropod resistance (the number of resistant species times the number of chemicals they are resistant to) now stands at more than 1,600 (30). Resistance has had major public health effects as well, as DDT-resistant mosquitoes have dashed hopes that malaria would soon be wiped out.

Areas that have suffered serious outbreaks of resistant pest epidemics include Indonesia, where 263,000 metric tons of rice were destroyed by brown planthoppers in 1975; northeastern Mexico, whose 280,000-hectare cotton industry has been wiped out since the 1960s by the boll weevil and the tobacco budworm; and Long Island in the northeastern United States, where farmers are spraying banned pesticides under special exemption up to ten times a season, polluting the groundwater in the process, and spending as much as $750 per hectare in a desperate attempt to control the Colorado potato beetle (31).

In response, the chemical industry and the world's agricultural research community have been gradually paying more attention to the concept of integrated pest management, a series of techniques that relies on smaller doses of more specifically targeted chemicals, the use of physical and biological controls, and sophisticated attention to the habits and life cycles of pests and their relationships to individual crops and agro-ecosystems. Although integrated pest management has been the subject of much discussion and research for well over a decade, its adoption has been slow, principally because it requires a high level of sophistication and cooperation on the part of farmers, extension agents, and pesticide sales personnel, and partly because in many cases it would mean a lower sales volume for chemical manufacturers (32).

### Multiple Cropping

In parts of the developing world with extreme land scarcity, notably South and East Asia, high-input agriculture—including new varieties of fast-growing seeds—has enabled farmers to grow two and even three crops per year on the same parcel of land. In fact, because of the extreme intensity of land use, the Asian centrally planned countries have a harvested-land-to-arable-land ratio of 1.34:1—one and a third hectares of food are grown on every hectare of land each year. (See Table 4.8.)

No other region uses land as efficiently, although the trend toward double-cropping is increasing in other areas where the soil can handle such intensive use. However, multiple cropping is only suitable in limited areas because it depends upon the replenishment of nutrients through heavy use of fertilizer as well as careful management of irrigation to prevent soil salinization. In China, for example, the "grain first" policies of the 1960s and 1970s led to triple cropping in parts of eastern and southern China where it cannot be sustained (33). Moreover, the practice can increase a region's vulnerability to a season of unusually bad weather, a pest or disease outbreak, or other problems.

**Table 4.7 Deaths From Accidental Pesticide Poisoning, Selected Countries and Years**

| Country | Year | Cases | Deaths Number | Deaths Percent |
|---|---|---|---|---|
| Cyprus | 1972 | 15 | 2 | 13 |
| Finland | 1974 | 131 | 16 | 12 |
| Ireland | 1974 | 141 | 2 | 1 |
| Israel | 1974 | 53 | X | X |
| W. Samoa | 1972 | 10 | X | X |
| Romania | 1974 | 2,740 | 303 | 11 |
| Syria | 1971 | 1,064 | 167 | 16 |
| Turkey | 1974 | 1,680 | 156 | 9 |
| United Kingdom | 1973 | 98 | 14 | 14 |
| **Total** | | **5,932** | **660** | **11** |

X = not available
**Sources:**
1. J.F. Copplestone, *Safe Use of Pesticides* (World Health Organization, Geneva, 1973).
2. J.E. Davies, "Health Effects of Global Pesticide Use," report prepared for the World Resources Institute (WRI) (WRI, Washington, D.C., 1985), pp. 4–5.

### Summary

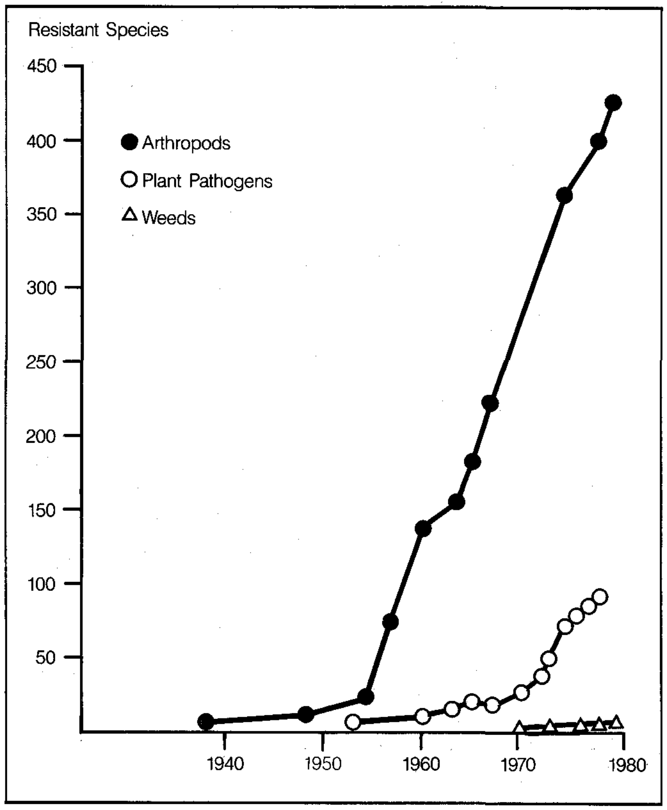
In conclusion, the vast proportion—about 88 percent—of the additional 400 million metric tons of grains that will be grown in the mid-1990s will be the result of improved productivity of current agricultural land, through the increased use of new irrigation, fertilizer, multiple cropping, and pesticides (34).

## AGRICULTURAL PRODUCTION AND CONSUMPTION

Between 1974 and 1983 world food production increased at an annual rate of 2.2 percent, almost 0.5 percent faster than population growth. The developing countries significantly outperformed the developed countries, even taking into account faster population growth in the Third World, and by the end of the ten-year period the developing nations as a whole increased their per capita food production by about 10 percent.

However, as a whole the 36 "least developed" nations (35) did not share in the per capita agricultural improvement because of much higher birth rates. Their rate of food production increase, 2.1 percent per year, was fully half a percentage point less than their population growth

**Figure 4.1 Number of Species Resistant to Pesticides, 1940-80**




**Source:** G.P. Georghiou and R.B. Mellon, "Pesticide Resistance in Time and Space," in *Pest Resistance to Pesticides*, G.P. Georghiou and T. Saito, eds. (Plenum Press, New York, 1983), pp. 1-46.

(36). These nations are in worse shape now than they were in the early 1970s—which itself was a period of such concern about agriculture that the United Nations initiated the World Food Conference.

For the ten years following that Conference, FAO projected that food production would increase in the developing world by an average of 2.6 percent per year. Ten years later, only Africa had not reached that goal. The rest of the developing world was able to make substantial agricultural progress on a per capita basis because the general rate of population growth was significantly lower than had been projected in 1974. Africa combined a less-than-hoped-for production increase with a higher-than-predicted birth rate (37). (See Table 4.9.)

The world's production of cereals, including wheat, rice, and coarse grains (primarily maize) reached a world total of 1.78 billion metric tons in 1984, the greatest amount in history and a remarkable 8.5 percent increase over 1983. However, the developing world's increase was just 2.3 percent, sufficient only to keep a step ahead of population growth. Meanwhile, much of the huge harvest in the industrialized world was unmarketable and went into stockpiles; by the end of the 1984–85 season, global cereal carry-over stocks were projected to reach 294 million metric tons or 18 percent of expected world consumption (38).

Throughout the 1970s, the fastest growth in cereal production was in North America, Latin America, and the centrally planned nations of Asia. In North America, with decreasing growth of population and demand, the huge production is shifting the U.S. and Canadian agricultural economies ever more toward the export market.

One of the more remarkable developments of the 1970s was the strong growth in meat production and consumption. By 1983–84 just over 50 percent of the world's grain production went to feed animals, not people. Everywhere but Africa (where per capita consumption fell) and the high meat consumption countries like Argentina, Australia, New Zealand, the United States, and Canada (where market saturation is apparently being reached), meat consumption was up sharply.

Rising incomes almost always create a rising demand for meat. This has been particularly apparent in the Middle East, East Asia, and in the less wealthy countries of Europe. In the 1970s, per capita meat consumption grew by 1 percent a year above population growth, and global production increased almost 3 percent a year. This rate of growth is expected to decline somewhat in the coming less prosperous years, but will continue. Even South Asia, with its low income and traditionally vegetarian diet, will exhibit growth, although by 1994 it will only bring per capita yearly consumption up to three kilograms (39).

Another indicator of rising meat production was the sharp growth in oilseed (primarily soybean) production and consumption (40). Oilseed is the key ingredient in high-protein animal feeds, upon which livestock herds in North America, Western Europe, and elsewhere are increasingly dependent.

Finally, the world produced about 22 million metric tons of fibers annually in the early 1980s, most importantly cotton, jute, and wool. Fiber sales have suffered from competition with synthetics for several decades, and per capita fiber consumption declined in the 1970s. The decline is expected to continue in the future, though at a lesser rate (41).

## WORLD FOOD TRADE

One of the most dramatic developments in agriculture has been the rapid rise in the volume of world trade since World War II, and particularly since the early 1970s. In the period 1950–72, while world agricultural production was increasing at an annual rate of 2.85 per-

**Table 4.8 Harvested Land as Percentage of Arable Land, 1970, 1981, and 1994**

| | 1970 | 1981 | 1994 |
|---|---|---|---|
| North Africa/Middle East | 58 | 58 | 59 |
| Sub-Saharan Africa | 73 | 75 | 75 |
| European Economic Community | 71 | 74 | 76 |
| Other Western Europe | 65 | 67 | 70 |
| USSR | 63 | 65 | 66 |
| Eastern Europe | 81 | 78 | 78 |
| South Asia | 95 | 97 | 96 |
| East Asia | 91 | 96 | 101 |
| Asian Centrally Planned Economies | 129 | 134 | 142 |
| Oceania | 30 | 41 | 44 |
| Latin America | 69 | 70 | 70 |
| North America | 46 | 59 | 60 |
| **World** | **72** | **76** | **78** |

**Source:** Adapted from Winrock International, 1985, Reference 8, p. 30.

**Table 4.9 Annual Percent Increase in Food Production and Population, 1974–84 and Extrapolation to 1985**

| | Food Production | | Population | |
|---|---|---|---|---|
| | 1974–84[a] | 1985[b] | 1974–85[a] | 1985[b] |
| Developing Market Economies | 3.0 | 2.6 | 2.5 | 2.7 |
| Africa | 1.9 | 2.5 | 3.1 | 2.9 |
| Far East | 3.6 | 2.4 | 2.3 | 2.6 |
| *Latin America* | 3.0 | 2.9 | 2.4 | 2.8 |
| Near East | 2.6 | 3.1 | 2.7 | 2.9 |
| Asian Centrally Planned Economies | 4.1 | 2.6 | 1.4 | 1.6 |
| *All Developing Countries* | 3.1 | 2.6 | 2.1 | 2.4 |

**Notes:**
a. Actual trend.
b. Extrapolations by the World Food Conference, 1974.
**Source:** United Nations, "The World Food Problem" *in U.N. World Food Conference* (FAO, Rome, November 1974).

cent, world agricultural trade was expanding by 4.95 percent. In the decade that followed (1972–81), trade burgeoned even faster, 6.25 percent a year, despite a drop in world production growth to 2.35 percent annually. (See Table 4.10.) If 1950 is taken as a base year, world agricultural trade volume had doubled by 1962, tripled by 1972, and quadrupled by 1980 (42). Moreover, the increased value of the exports was greater even than the increased volume (43).

About one of every ten kernels of grain crosses an international border between the time it is harvested and consumed. And for most kernels the trip involves crossing either the Atlantic or Pacific Ocean, for by the end of the 1970s fully 87 percent of grain exports originated in North America.

It is difficult to overstate the importance of North America, particularly the United States, in world grain trade. The United States is not literally "feeding the world," but it certainly provided the marginal increase in calories that improved the lot of millions of people in developing nations in the past decade. With the exception of North America (and, to a much smaller degree, Oceania and the European Economic Community), the world in the early 1980s was consuming annually almost 150 million metric tons of grain more than it was producing. In fact, these grain-deficit countries had increased their dependence on imports through the 1970s at the astonishing rate of 12.5 percent a year (44), although they were partially balancing that deficit through the export of many non-grain agricultural products.

In the coming decade the pattern is likely to continue, even if rates decline. By the year 2000, North America will be approaching the 200-million-metric-tons-per-year mark in exports. The European Economic Community will have become a substantial exporter, thanks to heavy production subsidies, but the output will be easily absorbed by the rest of Europe, which is grain short.

Why is world agricultural trade booming? What does it mean and where is it heading? The answers are complex, and future developments are difficult to predict.

Several coincidental events in the early 1970s combined to give world agricultural trade a boost. Among them were the liberalization of the foreign exchange regime with the end of fixed exchange rates, huge Indian and Soviet grain purchases in 1972, and the first major changes in U.S. stockholding policy since World War II. In addition, the psychological impact of the 1973 OPEC oil price increase led to a destabilization of grain markets as many nations made immediate purchases to avoid future price increases. Moreover, rising world affluence, particularly among the middle-income developing countries, placed many nations in the category of potential food buyers for the first time. (The Middle East, for example, converted much of its oil profits into grain-fed meat; meat imports in the region grew from under 100,000 metric tons in the early 1970s to over a million metric tons in the early 1980s.) Finally, credit was still being liberally extended in the 1970s and much of the growth in the global food trade was debt-financed. The tightening of credit in the early 1980s was partially responsible for the trade turndown from 1981–85.

The 1970s seem to have marked the passing of a psychological barrier to agricultural trade as well. The general presumption that nations should strive to be self-sufficient in food apparently began fading with the realization that other regions might be able to provide food, at least at the margin, more cheaply.

World trade maximizes production and consumption, and evens out regional peaks and valleys in production

**Table 4.10 World Trade in Grains, Meat, Milk, and Oilseed, by Region**

| | Grains | | Meat | | Milk | | Oilseed | |
|---|---|---|---|---|---|---|---|---|
| | One-Year Average, 1980-82 (million metric tons) | Average Annual Percent Change Over Previous Decade | One-Year Average, 1980-82 (million metric tons) | Average Annual Percent Change Over Previous Decade | One-Year Average, 1980-82 (million metric tons) | Average Annual Percent Change Over Previous Decade | One-Year Average, 1980-82 (million metric tons) | Average Annual Percent Change Over Previous Decade |
| North Africa/Middle East | –29.2 | 12.8 | –1.18 | 26.0 | –7.9 | 12.4 | –1.7 | –14.4 |
| Sub–Saharan Africa | –5.8 | 11.4 | –0.08 | –8.1 | –1.3 | 5.3 | 2.6 | –3.5 |
| European Economic Community | 4.3 | 2.0 | 0.12 | 1.0 | 11.3 | 17.9 | –31.1 | 5.6 |
| Other Western Europe | –11.0 | 8.5 | –0.03 | –14.8 | 1.0 | 3.8 | –5.6 | 5.7 |
| USSR | –36.5 | –22.7 | –0.80 | 23.9 | –4.3 | –14.5 | –2.7 | –23.3 |
| Eastern Europe | –11.4 | 5.5 | 0.49 | 13.9 | 0.3 | 5.0 | –6.4 | 8.0 |
| South Asia | –1.6 | –11.1 | 0.05 | 33.2 | –0.6 | 19.1 | 2.9 | 1.8 |
| East Asia | –28.8 | 4.9 | –0.82 | 8.5 | –1.9 | 3.9 | –8.1 | 4.7 |
| Asian Centrally Planned Economies | –18.6 | 12.1 | 0.23 | 3.4 | –0.1 | 6.6 | –1.2 | 44.1 |
| Oceania | 15.6 | 5.6 | 1.47 | 2.5 | 5.6 | –2.3 | 0.0 | 31.1 |
| Latin America | –7.6 | –10.9 | 0.56 | –2.5 | –2.2 | 4.0 | 16.0 | 10.8 |
| North America | 132.8 | 9.3 | 0.18 | 3.8 | –1.1 | 24.6 | 37.0 | 6.8 |
| **World Total[b]** | **152.7** | **7.8** | **3.10** | **3.2** | **18.2** | **6.5** | **58.5** | **6.2** |

**Notes:**
a. Negative amounts are imports. Positive amounts are exports.
b. Exports only.
**Source:** Adapted from Winrock International, 1985, Reference 8, pp. 43, 44, 47, and 48.

and prices. Thanks in part to booming international trade, world production has kept up with effective demand despite falling prices for grain and most other food products in 25 of the last 30 years. In all, real agricultural prices were 25 percent lower in 1980 than in 1950 (45).

Conversely, trade barriers tend to decrease prices for exporting producers, increase prices for consumers in importing countries, and lead to unnecessary shortages and surpluses. However, the internal pressure to protect various industries, crops, and economic groups is often intense, and virtually every government has erected one trade barrier or another. When food supplies are relatively tight, trade barriers are only a minor problem, but favorable weather years with large harvests and abundant supplies can trigger major trade disputes.

In the mid-1980s, because of huge harvests in Europe, the United States and the Common Market found themselves on the verge of a trade war. Low prices and high debts forced many American farmers into bankruptcy. At the same time, thanks to price supports given the politically powerful dairy industry, the United States found itself with enough surplus to give every American a two-month supply of butter, a three-month supply of cheese, and a two-month supply of milk (46), even though the price of dried milk was at its all-time high. Meanwhile, in Europe, agricultural subsidies were accounting for 79 percent of the entire budget of the European Economic Community (47).

As world trade burgeons, the traditional nation-based structure of agriculture is giving way. Suddenly, good weather in Europe can put an American farmer out of business, while a U.S. political decision on wetland protection requirements can raise the price of meat in Korea. Moreover, the traditional market forces of supply and demand are beginning to take a back seat to financial variables that have nothing to do with agriculture: currency exchange rates, debt-driven interest and government economic subsidies. Farmers are finding themselves worrying more about the rise of mortgage rates and the fall of currency prices than the rising of the sun and the falling of the rain.

Currency exchange rates have such a severe impact on agricultural prices that large chunks of the market are going underground and avoiding cash transactions entirely. Barter and its more complex variant, countertrade (three-, four-, and multi-way barter), have grown from marginal amounts (mostly within the Soviet Union and Eastern European countries) to more than 30 percent of all world food trade. Although they are practical solutions to a serious problem, barter and other forms of non-market transactions (like bilateral long-term contracts) are leading to greater government involvement in world food trade and less reliance on market mechanisms to make decisions and allocate resources.

## FOOD AID

When a nation can neither grow nor afford to import enough food for its citizens, it must appeal to the generosity of the better-off members of the world community. In 1974, the participants at the World Food Conference set a minimum target of providing 10 million metric tons of food aid annually to needy nations. However, the donor nations did not reach this goal until ten years later, when 10.4 million metric tons were made available in 1984, largely because of the catastrophic famine in Africa. But by then the amount was only a fraction of the real need. The FAO estimated that 111 countries required 20 million metric tons of food aid in 1985; the U.S. Department of Agriculture calculated that, based on nutritional needs, 67 low-income countries required 25.8 million metric tons (48). For the longer term, assuming an end to African drought, the United Nations World Food Program estimates an annual worldwide food aid need of approximately 14 to 15.5 million metric tons.

The largest food donors are the United States, the European Economic Community, Canada, Japan, and Australia. Fifty countries contribute either food or funds, including even India, China, Egypt, Mauritius, and Togo. The largest recipient countries in 1982–83 were Egypt, Bangladesh, Sri Lanka, Pakistan, and Ethiopia.

Food aid is controversial. Emergency food shipments to regions facing short-term famine are universally supported, as shown by the unprecedented outpouring of aid to Africa in 1985. (See "Recent Developments," below.) There is vigorous debate, however, about the efficacy of long-term food aid. Free or low-cost food can become incorporated into the general food economy of recipient countries, driving down the price of food and undermining the already-precarious financial position of poor farmers. With no incentive to grow food to sell, farmers remain unproductive and food aid becomes indispensable.

Critics also point to the extent to which food aid is a pawn in global power politics, with "friendly" or strategically sensitive developing countries receiving more aid and "unfriendly" or less politically important countries receiving less, regardless of need. Others see food aid as a disguised means of disposing of surpluses. Moreover, the donated food does not always make its way to those who truly need it; reports of corruption and malfeasance are common. The rural poor of many developing countries—who are predominantly women and children—are at particular risk because of their remoteness from food distribution centers and their lack of political power.

Nevertheless, food aid is strongly backed by politically powerful producers in the food-surplus nations and has become an accepted institution that currently comprises about five percent of total world food trade (and, in fact, is becoming difficult to distinguish from other components of that trade). While food aid may not be an appropriate long-term solution, the vast amount of hunger in the world, coupled with falling per capita agricultural production in many low-income developing countries, and rising foreign debts, guarantees that food aid will remain a substantial element of the world agricultural economy for a long time to come.

## FOCUS ON: EROSION

Soil erosion is as old as the planet. It causes major losses in agricultural and forest productivity; yet over time it has also been responsible for the productivity of such fertile areas as the Nile, Indus, Ganges, and Mississippi River valleys. Under normal agricultural conditions, the average erosion rate is estimated to be about 0.5 to 2.0 metric tons per hectare per year (49). Put another way, approximately one vertical centimeter of topsoil would be washed or blown away every 80 to 280 years, depending upon numerous related factors such as soil type, slope, and the nature and intensity of wind and rainfall. This rate is also the immutable pace at which new soil is created by nature.

However, as croplands become overworked and mismanaged, erosion often rises dramatically. Hard numbers are impossible to come by, for erosion is a notoriously site-specific phenomenon. The world's rivers are believed to deliver about 24 billion tons of sediment to the oceans each year (50). In addition, many billions of tons of eroded soil never make it to the sea; they either settle along stream bottoms or silt reservoirs behind the world's dams. One single dam, the Sanmer on China's Huang (Yellow) River, traps 400 million metric tons of sediment a year (51). Many more billions of tons are eroded by the wind; scientists in Hawaii can tell when spring plowing begins in China because they see the dust over the Pacific (52), and up to an estimated 400 million tons of North African sand are blown westward into the Atlantic every year (53).

That erosion is affected by both slope and human activities is readily apparent by studying the sediment load of some of the Earth's major waterways. India's Ganges River, which drains just over 1 million square kilometers of intensively worked farmland and heavily harvested forestland in India, Bangladesh, Nepal, and Tibet, delivers 1.46 billion metric tons of sediment to the Bay of Bengal every year. In contrast, the Amazon River, which drains a much larger area of relatively unspoiled tropical forest covering nearly 5.8 million square kilometers, carries only 363 million metric tons of sediment per year. On a drainage area basis, the riverborne erosion rate in the densely populated plains and mountains of northeastern India is more than 20 times higher than in the sparsely populated jungle of Brazil. (See Table 4.11.)

China's Huang River is the most sediment-laden river on earth. From just 668,000 square kilometers of drainage—much of it through the heavily eroded Loess Plateau south and west of Beijing—the river dumps 1.6 billion metric tons of soil into the East China Sea. In its middle reaches, the river carries about 700 kilograms of silt per cubic meter of water, or about 50 percent silt by weight, just under the level classified as liquid mud. As this silt has settled out over the centuries, the height of the river bottom has risen, forcing the construction of ever-higher dikes along the riverbanks. Today, as it approaches its mouth, the Huang River flows in a channel raised three to ten meters above the surrounding countryside (54).

Erosion is widely reported, though not most painfully felt at the country and regional level. In Guatemala, 40 percent of the productive capacity of the land has been lost because of erosion, and several areas of the country have been abandoned because agriculture has become uneconomic. In Turkey, planners estimate that 75 percent of the land is affected, with 54 percent severely or very severely eroded. In Haiti, which loses 14 million cubic meters of topsoil a year, there is no top quality soil left. Cleared areas of Nepal lose between 35 and 75 metric tons of soil per hectare per year, leading one observer to suggest that the country's most precious export is its soil (55). In India 13 million hectares are eroded by wind and nearly 74 million by water, an astonishing one-quarter of India's total land area (56). Since 1957 alone, China has lost about 11 percent of its arable land to erosion, desertification, and conversion to nonagricultural uses (57).

Many factors cause erosion, but the two most important are degree of slope and the amount of bare soil exposed to the elements. Research in Nigeria, for instance, revealed that land with a 1 percent slope, planted in cassava, suffered erosion of a modest three metric tons per hectare per year. On a 5 percent slope, however, erosion jumped to 87 tons, and on a 15 percent slope soil eroded at a disastrous 221 tons per hectare per year. At that rate, all the topsoil from the test plot would disappear in a decade (58).

Soil is left bare for many reasons. Often fields are left barren between harvest and planting time. After forest is cleared there is a period of exposure before crops are planted and germinate. And, of course, the soil between row crops is bare if it is not mulched.

A shift in cropping patterns in the U.S. state of Missouri in the 1930s provided dramatic evidence of the effect of row cropping on erosion. When land was in corn/wheat/clover rotation, with the clover providing a grass-like mat over the soil, erosion took place at the rate of 6.75 metric tons per hectare. When the land was converted to corn-only agriculture, erosion jumped to almost 49.2 metric tons per hectare, a seven-fold increase (59). The clover mat not only held the soil on its third of the fields but also apparently trapped airborne and waterborne soil particles from the other two thirds. However, most large

**Table 4.11 Estimated Annual Soil Erosion, Selected River Basins**

| River | Outflow | Area of Drainage Basin (thousand square km) | Average Annual Suspended Load (million metric tons) | Estimated Annual Soil Erosion From Field (metric tons per hectare) |
|---|---|---|---|---|
| Niger | Gulf of Guinea | 1,114 | 5 | 0 |
| Congo | Atlantic Ocean | 4,014 | 65 | 3 |
| Nile | Mediterranean Sea | 2,978 | 111 | 8 |
| Amazon | Atlantic Ocean | 5,776 | 363 | 13 |
| Mekong | South China Sea | 795 | 170 | 43 |
| Irrawady | Bay of Bengal | 430 | 299 | 139 |
| Ganges | Bay of Bengal | 1,076 | 1,455 | 270 |
| Huang (Yellow) | Yellow Sea | 668 | 1,600 | 479 |

**Source:** El-Swaify et al., Soil Erosion and Conservation in the Tropics, American Society of Agronomy (Madison, Wisconsin, 1982), p. 8.

farms in the United States have abandoned crop rotation because of the size and needs of giant farm machinery, and are substituting chemical fertilizer for declining inherent soil fertility.

Erosion damages and depletes the soil in complex, subtle ways. Most seriously, it reduces the water-holding capacity of soil by selectively removing organic matter and the finer particles; soils that have been seriously degraded by erosion can lose up to 93 percent of their water infiltration capacity (60). Erosion also removes soil nutrients such as phosphorous, potassium, nitrogen, and calcium, as well as soil organic matter; the nutrients can be replaced with synthetic inorganic fertilizer or with crops of nitrogen-fixing legumes. The organic matter must be restored by adding biomass from crop residue, mulch, etc. Finally, erosion can stunt plant growth by restricting the depth of soil available for vigorous root growth.

Erosion has two major kinds of effects: on- and off-site. On the eroding field itself, the loss of topsoil reduces the long-term productivity of the land. Numerous studies in the United States reveal a decline in corn yields of three to six bushels per acre for each inch of topsoil lost. For wheat the reductions are between 0.5 and 2.5 bushels per acre. On average, these diminished yields represent losses of 6 percent per inch of eroded topsoil for both crops (61).

In experiments where the entire topsoil was scraped off experimental plots, the results were—not surprisingly—far more dramatic. In Mexico, land deprived of 18 centimeters of topsoil grew only 0.6 metric tons of corn per hectare compared to 3.8 tons in the control field. In Nigeria, when 15 centimeters of topsoil were scraped off, corn yields plummeted from 6.5 metric tons per hectare to only one ton (62).

Off-site effects are also severe, not so much to food production as to the world's waterways. In the United States, which has carried out the most extensive investigations of erosion rates and effects, about 3 billion metric tons of sediment are washed into waterways each year (not counting Alaska and Hawaii), with off-site damages estimated at $6.1 billion. This damage includes a decline in fish populations, the loss of recreation potential, destruction of coral reefs, a decrease in the amount of water stored in reservoirs, the loss of hydropower potential, and the cost of dredging rivers and harbors for navigation (63).

In the Third World the decline in hydroelectric capacity due to sedimentation behind dams is particularly costly, since for many developing countries these expensive public works projects are expected to provide a basis for future economic growth. Pakistan's Mangla Reservoir is a case in point. Built with a 100-year life expectancy, it will fill up with silt at least 25 years and possibly even 50 years ahead of its time. In Colombia, because of heavy erosion in the upper watersheds, the Anchicaya Dam had lost 25 percent of its storage capacity only two years after it was completed (64).

Soil erosion has been called a "quiet crisis" and a "creeping catastrophe" because it is generally not visible to the farmer or the policy-maker until after much of the damage has been done. Moreover, it is difficult to convince wealthy landowners—much less impoverished subsistence farmers—to budget time and money for erosion control techniques whose payback period may be measured in years or even generations. In addition, in areas where the off-site effects of erosion are more damaging than the on-site effects, it may be unreasonable to expect farmers to expend resources to protect lands hundreds or thousands of kilometers downstream.

There is no single solution to erosion. Appropriate measures depend on site characteristics, and most control measures work best when taken together. On denuded hillsides, reforestation is needed both for controlling erosion and for providing fuelwood. In many areas, particularly in Africa, agroforestry—the interplanting of crops and trees, particularly nitrogen-fixing trees such as *leucena*—has been effective in restoring soil fertility and preventing erosion. Even without shifting to full-scale agroforestry, shelter belts of trees planted near cropland can help reduce wind erosion.

Terracing is the ancient and traditional method of reducing erosion, particularly in Asia. In early days, when population growth was gradual, there was time to build strong and well-designed terraces that have lasted for centuries. Today, particularly in Latin America, population pressure has forced people higher and higher onto extremely steep mountain slopes, and there is often no time to construct proper terraces. Poorly built terraces are a major contributor not only to soil erosion but also to death and destruction from the mudslides that have become so feared in the Andes.

Erosion on hillsides can also be caused by grazing animals, whose heavy steps break up the soil. Stall feeding of livestock can contribute to erosion control in such areas. (This method also allows the collection and use of manure.) Preventing overgrazing on steep slopes in drought-prone areas is also critical to maintaining the protection provided by vegetative cover.

Erosion is intimately tied to fuelwood shortages. Recycling of crop residues is essential for soil maintenance and protection against erosion. But when fuelwood is short, residues are diverted for use as fuel. In China, which suffers from acute energy shortages in its rural areas, as much as 75 percent of available residues are used for fuel; in the United States 70 percent are recycled (65).

The recently developed method of "no-till farming," in which crop residues are left as mulch on top of the field and small holes are punched through the mulch to plant the seeds, is a strikingly successful erosion-control strategy. However, the method may prove to have serious drawbacks, because it requires heavy use of herbicides to suppress the weed growth that tilling normally eliminates. The impacts of herbicide use on soil and water quality and on the development of resistance in weed species are not yet well explored. No-till and minimum-till agriculture (where narrow rows are tilled but the spaces in between are left unplowed) has spread very rapidly in the United States, expanding from 10 percent of harvested cropland in 1972 to an estimated 32.6 percent in 1984 (66). However, no-till agriculture is not widely used in other parts of the world.

Finally, data collection to fill the gaping holes in current knowledge of erosion rates, and education of farmers and policy-makers, are top priorities. Available statistics do not yet allow reliable projections of future erosion rates and impacts. We do know enough about the global agricultural situation, however, to realize that whatever erosion-control steps can be economically taken should be taken.

## AGRICULTURE IN AFRICA

While most of the developing world has been making slow but steady progress in either increasing its agricultural production or improving its economic ability to purchase food, Africa has been losing ground in the effort to feed itself. (See Figure 4.2.)

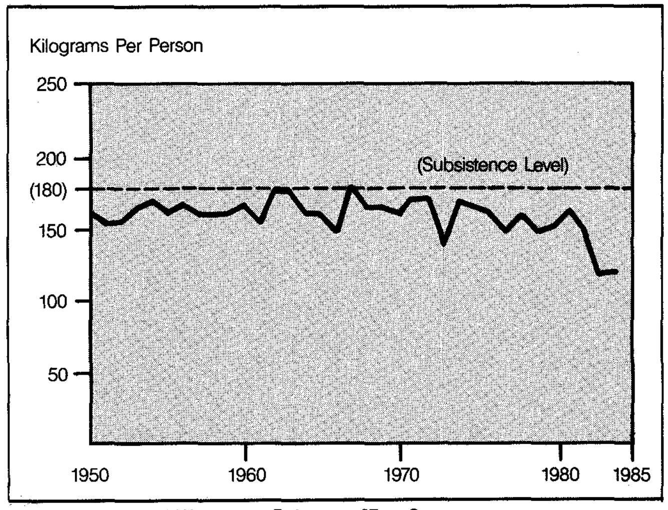
Virtually the entire continent, but particularly a huge arc of countries extending across the Sahel from Mauritania to Ethiopia and then south to Mozambique (see Figure 4.3), is caught in a dangerous cycle of rapid population growth, inability to afford technological advances in farming, expansion of agriculture onto marginal and sensitive lands, severe deforestation and erosion, declining agricultural productivity, and, too often, misguided agricultural policies combined with unaccountable state marketing institutions. Coupled with 17 years of below-average rainfall in most of the continent (67) plus three years of drought (see Chapter 8, "Freshwater," Box 8.1), these conditions have led to the starvation deaths of over a million people (68) and to the physical and psychological ravaging of uncounted millions more.

One of the major causes of Africa's food and development problems is the continent's population growth rate, which in the decade 1974–84 stood at 3.1 percent a year (69) and burdened farmers with about 1 million more mouths to feed every three weeks. At that rate Africa would have 1.5 billion people—three times its current population—to feed by the year 2025. Some of the demographic trends defy the imagination: current projections suggest that the population of Ethiopia will not level off until it reaches 181 million; and Nigeria's growth curve points to a hypothetical stationary size of 532 million inhabitants—about the current population of the entire continent (70).

Meanwhile, although it is the second largest continent, Africa is not particularly well suited to agriculture. Over 80 percent of its soils have fertility limitations, and the climate in 47 percent of the continent is too dry for rain-fed agriculture (71).

In earlier days, with less population pressure, Africans developed an indigenous agricultural regimen that suited the continent's unique ecology and served the people well, though at the subsistence level. Called "shifting agriculture" or the "bush fallow method," this system involved semi-nomadic cultivation, which allowed fields to recover nutrients and moisture for several years after a season or two of crop production. But increased population density and the advice of agricultural advisors from developed countries are leading Africans to abandon this type of farming in favor of methods that have proven successful in the more fertile and wetter parts of the world. Even if this shift in farming methods makes sense

**Figure 4.2 Per Capita Grain Production in Africa, 1950–84**



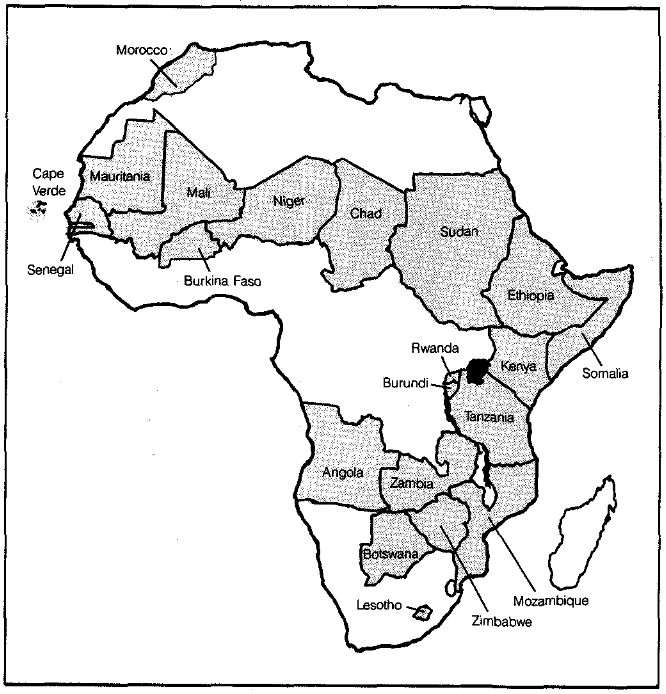

**Source:** Brown and Wolf, 1985, Reference 67, p. 9.

for the continent (which is far from certain), Africa does not now have the technological infrastructure to support such a change: irrigation systems are inadequate or nonexistent, fertilizer availability and use are far too low to replenish nutrients on intensively cropped lands, and there is insufficient capacity to handle the pest problems associated with repeat farming of plots. Moreover, there has been little cultural orientation toward soil conservation techniques, such as the terracing found in East Asia, because previous population densities generally did not warrant it.

Coupled with Africa's agricultural problems is the continent's acute energy shortage. Fuelwood is Africa's primary fuel, even in oil-exporting Nigeria. Both closed-canopy and open-canopy forests are being cut down at a high rate, with devastating effects on the soil. Not only are trees no longer there to cut the wind, anchor the soil, and reduce the erosive power of falling raindrops, but as fuelwood becomes scarce, people begin to switch to dried dung and other types of biomass that formerly returned nutrients to the soil.

The policies of most African nations must share the blame for the dismal state of the continent's agriculture. Most African governments have not invested enough money in agriculture. Between 1978 and 1982, while government spending per farmer increased in Latin America, the Near East, and the Far East, it declined by 0.1 percent a year in Africa, according to an FAO study (72). Similarly, African farmers do not receive high enough prices for what they produce to make it worthwhile to undertake the risks necessary for higher production or to invest in land conservation techniques. Many nations opt for low food prices to satisfy their urban poor rather than for higher producer prices to stimulate the farm sector. Some, such as Egypt, have also incorporated food aid shipments into their economies in a way that permanently undercuts their own farmers' ability to sell food. As one bitter relief worker in the Sahel put it, "Starve the city dwellers and they riot; starve the peasants and

**Figure 4.3 Twenty-one African Countries Affected by Abnormal Food Shortages, December 1984**




**Source:** U.N. Food and Agriculture Organization (FAO), 1985, Reference 48, p. 21.

they die. If you were a politician, which would you choose?" (73).

Finally, Africa (along with the rest of the developing world) was partly a victim of what now appears to have been bad advice from foreign development officials. Postwar development theory generally held that Third World countries could move directly from subsistence farming to industrialized economies, including "industrial agriculture"—cash-cropping of such commodities as coffee, cotton, pineapples, tea, and nuts—without establishing a strong, broad-based indigenous agriculture. In Africa particularly, resources were optimistically shifted to manufacturing while key infrastructure improvements in rural areas, such as roads connecting fields to markets and storage facilities, were put off. The net result is that not only has industrialization failed (for a variety of complex reasons), but agriculture also has been hurt, and food crops have fared worse than commercial crops.

With five exceptions (Cameroon, Central African Republic, the Ivory Coast, Rwanda, and Sudan), population growth has outstripped production in all 41 sub-Saharan countries. Per capita food production has dropped by a staggering 20 percent over the past decade in such countries as Angola, Ghana, Mozambique, Senegal, and Somalia. Even before the current drought, 25 percent of the population of the sub-Saharan nations had become dependent on imports for their food. Not since 1970 has the continent produced as much food as it consumed (74). Indeed, for the past 20 years, African commercial food imports have risen 9 percent a year (75).

Helping Africa rescue itself from further agony will be a long, difficult process. It will require new agricultural systems and technologies designed for Africa's soils and climates, and appropriate to its cultural, educational and financial conditions. Strategies to integrate agriculture, forestry, energy, and rural development will be vital. Massive amounts of tree planting, terracing, contour plowing and other soil conserving technologies will be necessary, as will new drought- and pest-resistant crop varieties. Traditional technologies, such as simple water harvesting and water conservation techniques, must be adapted to present conditions. Ways must be found to lessen the pressure on fuelwood resources. (See Chapter 7, "Energy," Focus on: Fuelwood Scarcity.) Strategies that allow the successful co-existence of pastoralist and settled agriculture in arid conditions must be developed. (See Chapter 5, "Forests and Rangelands," Primary Production in the Sahel, Box 5.1.)

Perhaps most important, African governments must reevaluate their agricultural policies to provide greater economic stimulus on the production side. Stimuli could include shifting the development focus from urban to rural areas; improving the quality and increasing the amount of agricultural research; allowing freer pricing policies for locally grown food; reorganizing the state-run crop marketing corporations to make them less corrupt, more efficient, and more accountable; and, certainly not least, expanding family planning services.

Policy changes carry the risk of significant political ramifications—the Sudanese government, for instance, was overthrown in April 1985, partially as a result of raising the price of bread—but they can also have dramatic positive results. Zimbabwe, one of the few African countries with effective pricing policies, produced a corn surplus of 800,000 tons in 1985, allowing it to provide 25,000 tons of grain as emergency food aid to Ethiopia.

## RECENT DEVELOPMENTS

### FAMINE IN AFRICA

In 1984 and 1985, Africa was the scene of both overwhelming human tragedy and its most stirring triumph, as first a terrible famine enveloped much of the continent and then a massive outpouring of world food aid was mobilized to save many from starvation. Very likely more than 1 million Africans died from malnutrition and related diseases, particularly in Sudan, Ethiopia, Niger, Mozambique, Somalia, Chad, and Mali, but millions more were saved by over $1 billion worth of food and aid donations from around the globe.

Both the famine and the relief effort were haunting repetitions of a similar catastrophe that struck the continent in 1973–74. Although the recent relief campaign was bigger, better-coordinated, and included for the first time the significant involvement of non-government organizations, the agricultural debacle was stark proof that, on the policy level, little had been learned since the previous famine. While in the short term the international community responded effectively to the crisis, in the long term, business-as-usual in African development potato is native to the Andes, corn to Mexico, coffee to Africa, and wheat to Ethiopia. The Third World still has tens of thousands of wild varieties of these and other crops with genetic characteristics that could improve present crops, and that will be needed to adapt current varieties to future conditions.

As a form of protectionism, some developing countries have clamped down on the free utilization of their genetic resources; Cuba, for instance, bans the export of tobacco seed, and Ethiopia forbids shipment of coffee seed. The answer does not appear to lie in trade restrictions, however, since both North and South benefit from seed improvements and from the safest possible storage of precious seed stock no longer found in the wild.

The recent decision attempts to shift the balance of power in the direction of the developing nations in three significant ways:

1. Instead of the current ad hoc, informal structure of CGIAR, the seed banks would become an official part of the FAO (and, hence, the United Nations), in which Third World nations have a voting majority.
2. For the first time, there would be a fund for training Third World scientists in genetic research (though many have been trained under the present system).
3. Most important, the patenting of new seed varieties would not be allowed and all countries could make use of new varieties without charge.

However, most of the developed nations (including the United States, which provides 25 percent of FAO's budget) are satisifed with the present system and feel that the charges of "genetic imperialism" being leveled against them are without merit. They are so strongly opposed to the proposed new banks that they are threatening not to join or fund the system. Such an action could result in two parallel seed bank structures, or it could so undermine the new proposal that it would collapse before it starts.

## References and Notes


1. U.N. Food and Agriculture Organization (FAO), *Agriculture: Toward 2000* (FAO, Rome, 1981), p. 21 (extrapolation).
2. Resources for the Future, "U.S. Food and Fiber—Abundance or Austerity?", *Resources*, No. 76, p. 4 (1984).
3. *Ibid.*, pp. 2–20.
4. R. Dudal, *et al.*, "Land Resources for the World's Food Production" in *Managing Soil Resources to Meet the Challenges to Mankind*, 12th International Congress of Soil Science (New Delhi, India, February 1982), p. 5.
5. G.W. Fadley and S.G. Moutappa, *Bioenergy in Developing Countries*, Vol. V (Elsevier Applied Science Publications, Barking, England, 1985).
6. L. Timberlake, *Africa in Crisis* (Earthscan, London, 1985), p. 97.
7. D. Avery, "U.S. Farm Dilemma: The Global Bad News is Wrong," *Science*, Vol. 230, p. 409 (October 25, 1985).
8. Winrock International, *World Agriculture: Review and Prospects into the 1990s; a Summary* (Winrock International, unpublished, Morrilton, Arkansas, April 1985), pp. 28–29.
9. U.S. Department of State Bureau of Intelligence and Research, *World Food Productivity for the 1990s; Summary*, Report 442–AR (U.S. Department of State, Bureau of Intelligence and Research, Washington, D.C., August 4, 1982), p. 3.
10. World Resources Institute (WRI), *et al.*, *Tropical Forests: A Call for Action*, Part I (WRI, Washington, D.C., October, 1985), p. 7.
11. *Op. cit.*, 1, p. 61.
12. *Op. cit.* 10, p. 33.
13. *Op. cit.* 8, p. 33.
14. *Op. cit.* 9, p. 408.
15. Farmland Preservation Survey, "All Is Flux, Nothing Stays Still," in *Farmland Preservation Survey*, Vol. II, No. 1, (Farmland Preservation Survey, Bethesda, Maryland, March 1983), p. 1.
16. *Op. cit.* 1, p. 20.
17. *Op. cit.* 1, p. 21 (extrapolation).
18. *Op. cit.* 8, p. 34.
19. W.R. Rangeley, "Irrigation and Drainage in the World" (Conference on Water and Water Policy in World Food Supplies, Texas A&M University, Texas, May, 1985), p. 24.
20. M. Yudelman "The World Bank and Agricultural Development—An Insider's View" (World Resources Institute, Washington, D.C., 1985), p. 22.
21. M.W. Holdgate, *et al.*, *The World Environment 1972–1982* (United Nations Environment Program, Dublin, 1982), p. 267.
22. Center for Science and Environment (CSE), *The State of India's Environment: A Citizen's Report, 1982* (CSE, New Delhi, 1982), pp. 6–7.
23. Center for Science and Environment (CSE), *The State of India's Environment, 1984–85: The Second Citizen's Report* (CSE, New Delhi, 1985), p. 18.
24. *Op. cit.* 1, p. 67.
25. *Op. cit.* 1, p. 66.
26. *Op. cit.* 8, p. 34.
27. M. Dover and B. Croft, *Getting Tough: Public Policy and the Management of Pesticide Resistance* (World Resources Institute, Washington, D.C., 1984), p. v.
28. C. Pearson, *Down to Business: Multinational Corporations, the Environment, and Development* (World Resources Institute, Washington, D.C., January 1985), p. 55.
29. J.F. Copplestone, "A Global View of Pesticide Safety," in *Pesticide Management and Insect Resistance*, D. Watson and A.W. Brown, Eds. (Academic Press, New York, 1977), p. 150.
30. G.P. Georghiou and R.B. Mellon, "Pesticide Resistance in Time and Space," in *Pest Resistance to Pesticides*, G.P. Georghiou and T. Saito, Eds. (Plenum Press, New York, 1983), pp. 1–46.
31. *Op. cit.* 27, pp. 9–11.
32. *Op. cit.* 27; for a discussion of what IPM is and is not, see pp. 43–52.
33. V. Smil, "China's Food" *Scientific American*, p. 124 (December 1985).
34. *Op. cit.* 8, p. 51.
35. For list of "least developed" nations see Appendix B.
36. U.N. Food and Agriculture Organization (FAO), *The State of Food and Agriculture 1984* (FAO, Rome, 1985), p. 47.
37. *Ibid.*, pp. 47–48.
38. *Ibid.*, p. 9.
39. *Op. cit.* 8, pp. 19 and 36.
40. *Op. cit.* 8, p. 24 and pp. 39–40.
41. *Op. cit.* 8, p. 40.
42. P.M. O'Brien, *The Functioning of the World Food Market and Its Impact on the World Food Outlook*, Staff Report (United States Department of Agriculture/Economic Research Service, Washington, D.C., January 1983), Tables 1 and 2, pp. 12–13.
43. *Op. cit.* 8, p. 42.
44. *Op. cit.* 8, p. 46.
45. *Op. cit.* 42, p. 3.
46. *Washington Post*, "Senate Rejects Cut in Dairy Supports" (November 20, 1985, Washington, D.C.), p. 47.
47. B. Insel, "A World Awash in Grain," *Foreign Affairs*, Vol. 63, No. 4, p. 900 (Spring 1985).
48. U.N. Food and Agricultural Organization (FAO), *World Food Report 1985* (FAO, Rome, 1985), p. 12.
49. D. Pimental, *et al.*, *World Food Economy and the Soil Erosion Crisis* (Cornell University, unpublished, May 1985), p. 3.
50. S. Judson, "Erosion of the Land, or What's Happening to Our Continents?", *American Scientist*, p. 356 (July/August 1968).
51. A. Sfeir-Younis, *Soil Conservation in Developing Countries: A Background Report* (The World Bank, unpublished, Washington, D.C.), p. 96.
52. J.R. Parrington, *et al.*, "Asian Dust: Sea-

sonal Transport to the Hawaiian Islands," *Science* (April 8, 1983).
53. J.M. Prospero, *et al.*, "Atmospheric Transport of Soil Dust from Africa to South America," *Nature* (February 12, 1981).
54. *Op. cit.* 49, p. 95.
55. *Op. cit.* 49, pp. 65–66.
56. *Op. cit.* 22, p. 1 and *op. cit.* 23, p. 18.
57. *Op. cit.* 33, p. 124.
58. P.O. Aina, *et al.*, quoted in R. Lal, "Effective Conservation Farming Systems for the Humid Tropics," in *Soil Erosion and Conservation in the Tropics*, Special Publication No. 43 (American Society of Agronomy, Madison, Wisconsin, 1982).
59. L.R. Brown and E.C. Wolf, *Soil Erosion: Quiet Crisis in the World Economy*, Worldwatch Paper #60 (Worldwatch Institute, Washington, D.C., September 1984), p. 11.
60. *Op. cit.* 49, p. 4.
61. L. Lyles, "Possible Effects of Wind Erosion on Soil Productivity," *Journal of Soil and Water Conservation* (November/December 1975).
62. *Op. cit.* 49, p. 7.
63. E.H. Clark II, *et al.*, *Eroding Soils; The Off-Farm Impacts* (Conservation Foundation, Washington, D.C., 1985), p. xviii.
64. *Op. cit.* 59, p. 29.
65. *Op. cit.* 33, p. 124.
66. *Op. cit.* 59, p. 33.
67. L.R. Brown and E.C. Wolf, *Reversing Africa's Decline*, Worldwatch Paper #65 (Worldwatch Institute, Washington, D.C., June 1985), p. 20.
68. *Ibid.*, p. 8.
69. *Op. cit.* 8, p. 49.
70. The World Bank, *World Development Report 1985* (The World Bank, Washington, D.C., 1985), Table 19.
71. U.N. Food and Agriculture Organization (FAO), *Land, Food and People* (FAO, Rome, 1984), pp. 5–7.
72. U.N. Food and Agriculture Organization (FAO), *How Development Strategies Benefit the Rural Poor* (FAO, Rome, 1984).
73. *Op. cit.* 6, p. 5.
74. M. Strong, "Beyond the Famine—New Hope for Africa," David Davies Memorial Lecture (Institute of International Studies, London, 1985), p. 9.
75. U.S. Department of State *Africa: The Potential for Higher Food Production*, Special Report No. 125 (Washington, D.C., April, 1985), p. 1.
76. United Nations, "Forward-Looking Strategies," in *World Conference to Review and Appraise the Achievements of the United Nations Decade for Women* (United Nations, Nairobi, Kenya, 1985), paragraphs 174–185 and 221.

# 5. Forests and Rangelands

Forests cover roughly one third of the world's land area. Wood and forest products provide income and employment for millions, essential raw materials, and fuelwood, which is the main source of household energy in the developing world. Worldwide, trade in forest products exceeds $100 billion annually.

Rangelands (1) represent another important land use, especially in arid and semi-arid regions. These lands, which cover almost half of all ice-free land, include various vegetation types from arctic tundra to alpine meadows and tropical and temperate grasslands. On some lands, grass grows under a sparse tree canopy. These are sometimes counted as rangelands and sometimes as "open forests."

In many countries forests and rangelands are poorly managed and their productivity is declining. Some countries, particularly in Africa and South America, are pushing forest and range resources to their ecological limits. Managers often lack the data needed to make sound decisions. Though both these ecosystems suffer from a lack of good information, the data on range resources are especially poor. Comparatively, analysts can put much more stock in forestry statistics than in rangeland data.

## CONDITIONS AND TRENDS

### FOREST RESOURCES

Before large-scale disturbances by humans, the world's forests and woodlands probably covered 6 billion hectares. By 1954, the total had declined to approximately 4 billion hectares. This 30 percent reduction reflects the increasing use of land for agriculture, pasture, and settlements. (See Part IV, "Land Use and Cover," Table 4.2.)

Worldwide, about 2.8 billion hectares (or 69 percent of the forested areas) are covered with closed forests (2), and 1.3 billion hectares are less densely wooded open forests. Forest regrowth on fallowed cropland covers an additional 406 million hectares, and natural shrublands and degraded forests in developing countries cover 675 million hectares. When these two categories of wooded land are added to open and closed forests, the total (5.2 billion hectares with woody vegetation) represents about 40 percent of the world's total land area. (See Table 5.1.)

Trees outside forests that are in windbreaks, along rights-of-way, or around farm fields, etc., are also important resources, especially in densely populated areas. Some 20 percent of Rwanda's farmland is maintained by farmers as woodlots and wooded pasture. These roughly 200,000 hectares of dispersed trees exceed the combined area of the country's remaining natural forests and state and communal plantations (3). In the Kakamega District of Kenya, over 90 percent of the farms have scattered tree cover, 79 percent of the farmers plant trees, and 64 percent of the farms have woodlots (4). Of the 7.2 billion trees planted in the densely settled plains region of China, 5.8 billion have been planted around homes and in villages, with each household tending an average of 74 trees (5). Even in France, where trees are not used for

**Table 5.1 Distribution of the World's Forest Lands, 1980 and 1985**
*(millions of hectares)*

| Region | Total Land Area | Closed Forest: Broadleaved[a] | Closed Forest: Coniferous | Open Forest | Total Forest Area | Percent of Total Land Area Forested | Other Wooded Land: Shrubland[b] | Other Wooded Land: Forest Fallow[c] | Total Wooded Area[d] | Percent of Total Land Area Wooded |
|---|---|---|---|---|---|---|---|---|---|---|
| **1980 World Totals** | **13,077[e]** | **1,827** | **1,121** | **1,372** | **4,320** | **33** | **624** | **407** | **5,381** | **41** |
| **1985 World Totals** | **13,077** | **1,726** | **1,139** | **1,282** | **4,147** | **32** | **675** | **406** | **5,228** | **40** |
| North America[f] | 1,835 | 168 | 301 | 215 | 684 | 37 | X | NA | 684 | 37 |
| Europe | 472 | 65 | 88 | 21 | 174 | 37 | X | NA | 174 | 37 |
| USSR | 2,227 | 147 | 645 | 128 | 920 | 41 | X | NA | 920 | 41 |
| Other Countries[g] | 950 | 50 | 22 | 70 | 142 | 15 | X | NA | 142 | 15 |
| **Developed Countries Subtotal** | **5,484** | **430** | **1,056** | **434** | **1,920** | **35** | **X** | **NA** | **1,920** | **35** |
| Africa | 2,966 | 216 | 2 | 500 | 718 | 24 | 450 | 160 | 1,328 | 45 |
| Latin America | 2,054 | 666 | 26 | 250 | 942 | 46 | 150 | 170 | 1,262 | 61 |
| Asia (except China and Oceania) | 1,640 | 317 | 30 | 83 | 430 | 26 | 45 | 76 | 551 | 34 |
| China | 933 | 97 | 25 | 15 | 137 | 15 | 30 | X | 167 | 18 |
| **Developing Countries Subtotal** | **7,593** | **1,296** | **83** | **848** | **2,227** | **29** | **675** | **406** | **3,308** | **44** |

X = not available
NA = not applicable
**Notes:**
a. Includes bamboo and mangrove formations.
b. Includes area with woody vegetation greater than 0.5 meters and less than 7 meters in height; counted by the Food and Agriculture Organization as "other land" (see Table 5.12).
c. Includes wooded areas with forest regrowth following clearing for shifting cultivation within the past 20 years.
d. Includes forest area and other wooded land.
e. "World totals" exclude Antarctica.
f. Canada and the United States.
g. Australia, New Zealand, Japan, Israel, and South Africa.
**Sources:**
1. For 1980 world totals: U.N. Food and Agriculture Organization (FAO), 1985, Reference 10.
2. For 1985 world totals: R. Persson, unpublished report to Swedish International Development Authority (1985), Tables 1, 2 and 4.
3. For total and regional land area: (FAO), 1984, Reference 13.

fuelwood, trees outside the forest occupy 883,000 hectares, or 6 percent of the country's forested land. (6).

Excluding forest fallow, shrubland, and trees outside the forest, closed forests and open woodlands still cover three times as much area globally as croplands and 75 percent more than grasslands (7). Today, forests and woodlands account for 66 percent of the net primary productivity of terrestrial ecosystems; of that productivity, tropical forests account for 75 percent (8).

The world's coniferous forests, the source of most industrial wood production, cover 1.4 billion hectares. Some 85 percent of them are in North America and the USSR. Non-coniferous (9) forests cover 2.8 billion hectares, or 67 percent of the world's forest area. About 1.6 billion hectares of these forests are found in South America and Africa, with another 600 million hectares in Asia and Oceania (10). (See Figure 5.1.)

Forests in temperate regions cover approximately 2 billion hectares, with 75 percent (1.6 billion hectares) of these forests categorized as closed (11). Closed tropical forests cover about 62 percent of the area of tropical forests (12). Slightly more than half the world's forests are in developing countries, where they cover 2.3 billion hectares, or 30 percent of the land area (13). In developed countries, forested areas amount to approximately 1.8 billion hectares or about 34 percent of these countries' land area (14).

Tropical forests—including closed forests, open forests, shrubland, and forest fallow—cover nearly 3 billion hectares worldwide. An area roughly equal to one fifth of closed and open tropical forests now lies fallow—the result of clearing by shifting cultivators within the past 20 years. Closed broadleaved coniferous and bamboo forests in the tropics covered 1.2 billion hectares in 1980 (15). Latin America includes the largest expanses of closed tropical forests. Two thirds of all open tropical forests are in Africa. The percentage of wooded land is lowest in tropical Asia (47 percent).

Forest resources are divided unevenly among countries, reflecting great variations in rainfall, temperature, land use, total land area, and population density. The Soviet Union has the largest area of forest (928 million hectares). Fifty-two percent of the world's closed tropical forests are found in Brazil, Indonesia, and Zaire. Together the 25 most extensively forested countries, which comprise 45 percent of the world's population, include 3.2 billion hectares (74 percent) of the world's forest area. The Soviet Union, Canada, and the United States together have 1.7 billion hectares, or nearly 54 percent of the world total. (See Table 5.2.)

## Changes in Forest Distribution

Evaluating long-term trends is difficult without more and better data on forest resources. But one recent assessment (16) indicates that, historically, the greatest relative changes in the vegetation cover have occurred in temperate regions. Since large-scale land clearing for agriculture began around 8000 B.C., grasslands have been reduced by 45–47 percent, and cold-deciduous forests (evergreen and temperate evergreen seasonal broadleaved forests) have been reduced by 32–33 percent. (See Part IV, "Land Use and Cover," Table 4.2.) In contrast, most types of natural climax tropical vegetation have been reduced in area by 15–20 percent over the past several millenia. Some 24–25 percent of all wooded savannas and tropical/subtropical deciduous forests have been cleared, while until recently only slight losses (4–6 percent) of tropical evergreen rainforests and tropical/subtropical evergreen needle-leaved forests have occurred.

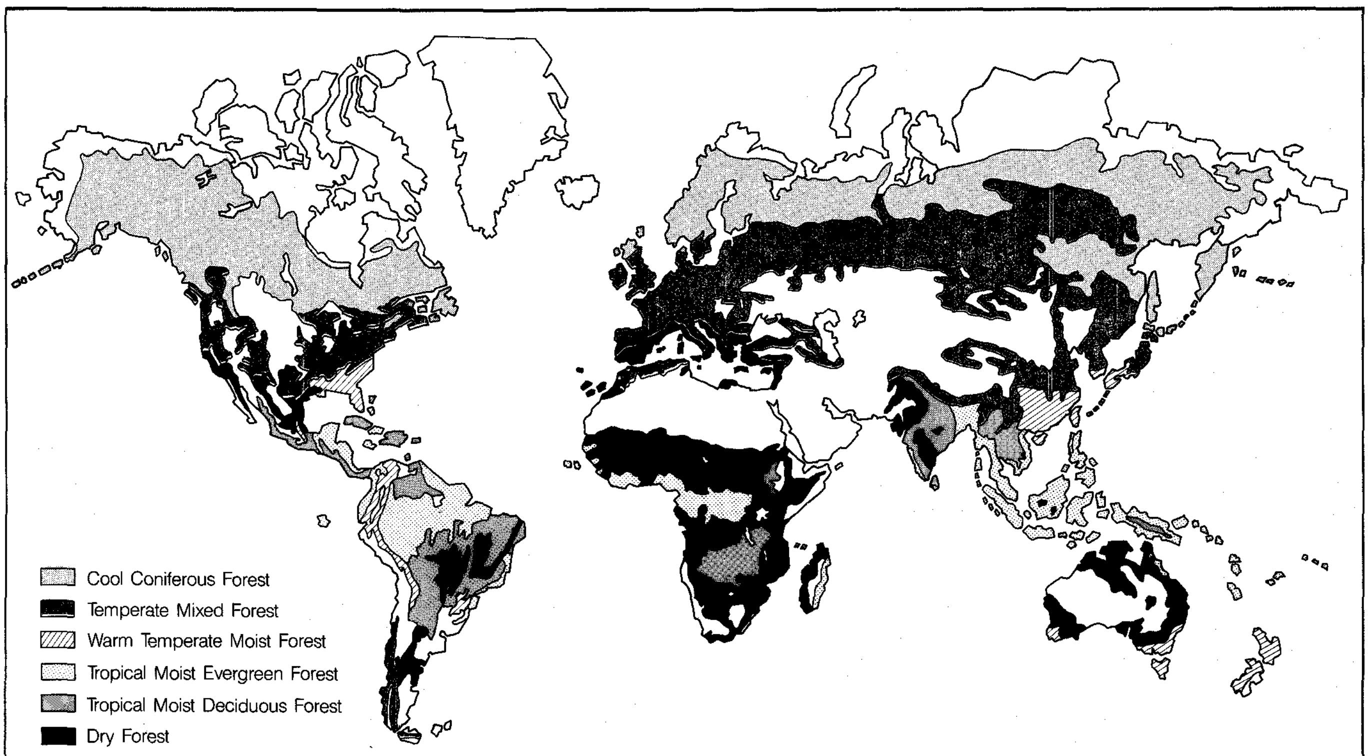
Changes in forest areas in the tropics have far outstripped those in temperate regions. Temperate forests in Europe, Asia, and Oceania have grown slightly over the past few decades because reforestation and reversion of cropland to forestland have more than offset losses to urbanization, roads, and other uses. In North America, the total forested area increased steadily in the early 20th Century, after centuries of decline. More recently, however, the total has again dropped slightly. In contrast, the area of forests and woodlands declined from 115 to 71 million hectares in Central America and from 901 to 690 million hectares in Africa between 1950 and 1983 (17).

Of course, aggregate changes obscure differing trends among and within different countries. Estimates of forest area reveal little about the condition of forest resources (e.g., changes in the density of the tree cover or in the productivity or composition of forests). In general, as long as tree cover appears to exceed 10–20 percent, an area is considered forested, even though the forest may have been significantly degraded and the number of trees per hectare reduced from several hundred to less than 50.

Comparatively good data make changes in Europe's forest area relatively easy to examine. (See Figure 5.2.) Net increases in forest area over the past few decades, despite high population densities and land use pressures, are largely the result of increased productivity on farmlands. This productivity, coupled with greater public recognition of forests' economic and aesthetic values, has been complemented by tax incentives and other support programs designed to sustain or increase domestic wood supplies, the growth of forest product imports, and the efforts to keep forests as part of the landscape (18). For example, Turkey planted 150,000 hectares a year during the 1970s while Finland drained and afforested peat lands and restocked other wooded lands and once-abandoned cropland. In Norway and Sweden, reduced grazing pressure and the release of agricultural land, together with government reforestation programs, have greatly increased the overall forest area. In Ireland and the United Kingdom, similar increases stem from government and private tree-planting activities, which amounted to 10,000 hectares in Ireland and 30–40,000 hectares in the United Kingdom annually in the late 1970s and early 1980s. In Hungary, Czechoslovakia, and the Netherlands, reforestation programs also significantly boosted forest area. Even where net changes have been insignificant, compensating changes in land use often mask reforestation and forest renewal. For example, recently the Federal Republic of Germany has been losing about 10,000 hectares of forestland each year to urbanization and other developments, but it has been reforesting marginal agricultural land even faster (19). In the United States, however, forest area has been gradually decreasing as a result of conversion to cropland, urbanization, water impoundments, mining, and other uses of forestland. Between 1963 and 1980, total forest area in the United States declined from 307 to 290 million hectares (20).

In tropical regions, deforestation rates have exceeded reforestation by 10–20 times in recent years. Average annual deforestation is greatest in Latin America, especially in the unproductive (21) and logged-over closed forests of the tropics. Deforestation rates are also high in

**Figure 5.1 Main Vegetation Zones of the World's Forests**




**Source:** U.N. Food and Agriculture Organization (FAO), *Unasylva*, Vol. 28, No. 112–113 (1976).

Africa's open forests. In the unproductive closed forests of Africa and Asia, deforestation rates have been relatively low: in 1980, losses equaled about 0.6 percent of remaining forests in all three regions, though exact amounts and rates varied more than a hundredfold among countries.

A driving force behind the loss of forestlands has been the conversion of forests to agricultural land. Since 1976, 6–8 million hectares of closed forests and nearly 4 million hectares of open forests and woodlands have been cleared each year for agriculture (22). Annually, 4–5 million hectares of productive closed forests are logged, and over 90 percent of this area later becomes cropland. Another 14.5 million hectares of forest fallow are cleared each year; of that fallow, 3.3 million hectares are converted to permanent agriculture and the remainder returned to forest fallow by shifting cultivators (23).

## Productivity and Growing Stock of Forests

About two thirds of all closed forest is commercially exploitable. In Europe, 133 million hectares (92 percent) of the closed forests are considered commercial, of which 121 million hectares are stocked (24). In the United States, 195 million hectares (65 percent) of closed forests are commercially productive, and 189 million hectares are stocked. By contrast, 886 million hectares (74 percent) of closed tropical forests are considered productive, while 274 million hectares of closed forests and 369 million hectares (50 percent) of open forests are either poorly stocked or are inaccessible (25).

The available data suggest that, worldwide, the growing stock of commercially exploitable living trees has decreased slightly, whereas the amount of wood harvested has steadily increased. Forest regrowth in temperate climates has masked decreases in the tropics. For example, 169 million hectares (or 20 percent) of all productive closed forest in tropical countries has already been logged (26). The United Nations Environment Program (UNEP) reported in 1982 that only 400 million hectares (10 percent) of the world's forestlands are sufficiently well-stocked to yield more than half their potential production. Yields on 3.3 billion hectares (80 percent) of the world's forestlands are estimated at less than 20 percent of the potential maximum as a result of depletion of growing stock, erosion, and site degradation (27).

# FOREST MANAGEMENT

In the early 1960s, the U.N. Food and Agriculture Organization (FAO) estimated that management plans had been prepared for 975 million hectares (23 percent) of the world's forests (28). Most areas were not being "intensively managed" (29), but logging practices had been prescribed and some provision made for post-harvest regeneration. Currently, less than 25 percent of the world's forests are actually managed, and most of them are in the Soviet Union. In tropical countries, intensively managed forests have decreased in area over the past two decades.

The depletion of natural forests in Europe and the United States in past centuries prompted vigorous efforts to renew and sustain supplies of wood fiber. As a result,

## Table 5.2 Forest Areas in Selected Countries, 1980

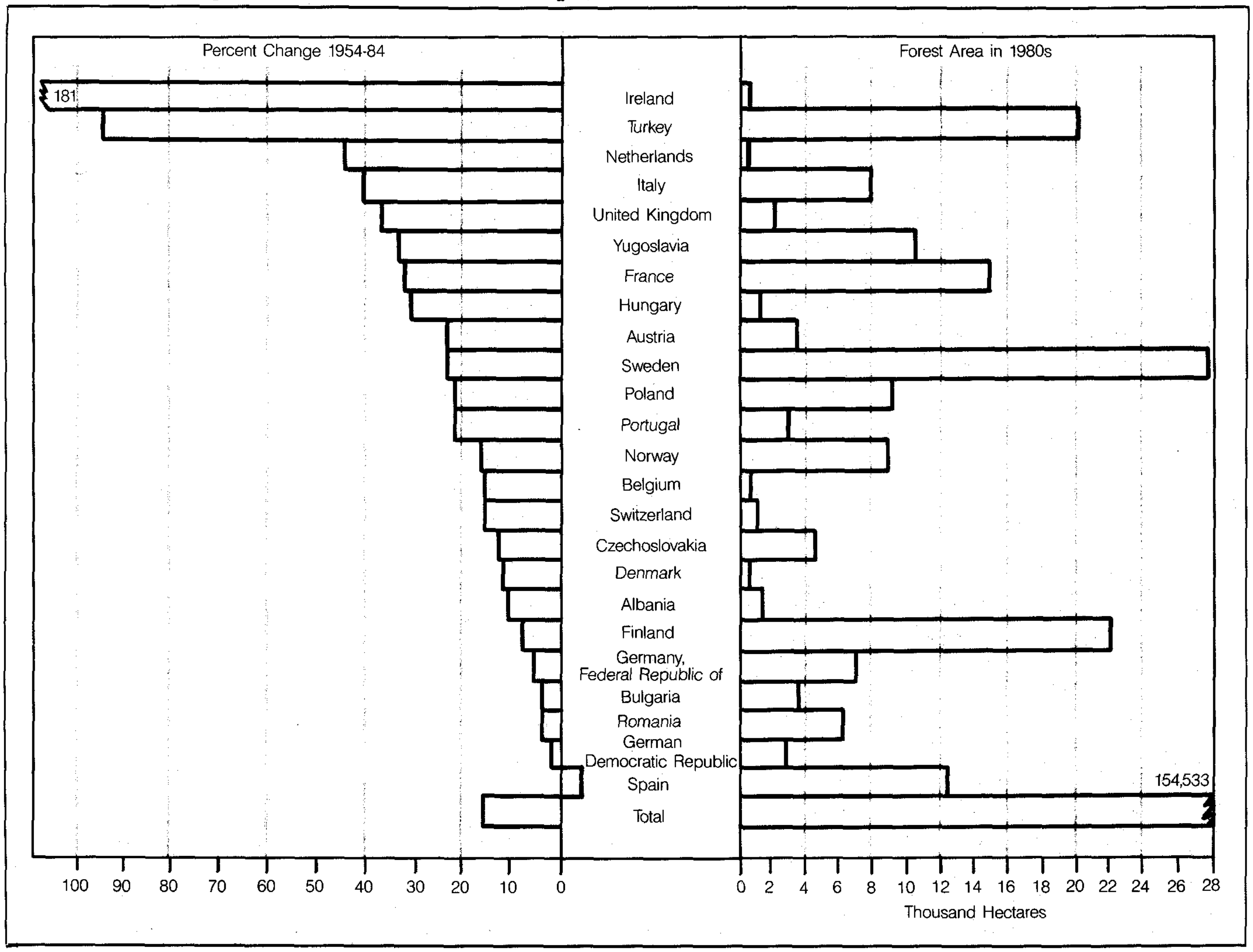
| Country | Forest Area (thousand ha) | Percent of Total Land |
|---|---|---|
| **Countries with Large Areas of Forest** | | |
| USSR | 928,600 | 41.5 |
| Brazil | 553,030 | 65.0 |
| Canada | 436,400 | 43.7 |
| United States | 298,076 | 31.8 |
| Zaire | 177,815 | 75.8 |
| China | 170,000 | 17.7 |
| Indonesia | 126,235 | 66.3 |
| **Countries with High Percentage of Forested Land** | | |
| Peru | 71,640 | 55.7 |
| Bolivia | 66,763 | 60.8 |
| Paraguay | 30,360 | 74.6 |
| Guyana | 18,512 | 86.1 |
| Suriname | 15,605 | 95.6 |
| Ecuador | 14,679 | 51.8 |
| Central African Republic | 35,895 | 57.6 |
| Botswana | 32,560 | 54.2 |
| Cameroon | 25,805 | 54.3 |
| Congo | 21,508 | 62.9 |
| Gabon | 20,765 | 77.6 |
| Senegal | 11,170 | 56.9 |
| Papua New Guinea | 38,392 | 83.2 |
| Malaysia | 21,256 | 64.5 |
| Laos | 13,735 | 58.0 |
| Kampuchea | 12,716 | 70.2 |
| Japan | 25,280 | 67.9 |
| Finland | 23,225 | 68.9 |
| **Countries with Low Percentage of Forested Lands** | | |
| Libya | 460 | 0.3 |
| Algeria | 2,990 | 1.3 |
| Niger | 2,960 | 2.3 |
| South Africa | 4,150 | 3.4 |
| Tunisia | 750 | 4.6 |
| Kenya | 3,860 | 6.6 |
| Mali | 8,819 | 7.1 |
| Saudi Arabia | 1,200 | 0.6 |
| Syria | 420 | 2.3 |
| Afghanistan | 1,500 | 2.3 |
| Iraq | 1,910 | 4.4 |
| Israel | 100 | 4.8 |
| Pakistan | 4,080 | 5.1 |
| Iran | 12,400 | 7.5 |
| Haiti | 58 | 2.1 |
| Uruguay | 580 | 3.3 |
| El Salvador | 155 | 7.4 |
| Ireland | 380 | 5.4 |
| United Kingdom | 2,178 | 8.9 |
| Netherlands | 355 | 9.5 |

**Source:** U.N. Food and Agriculture Organization (FAO), 1985, Reference 10.

83 million hectares (58 percent) of Europe's closed forests are now managed according to a plan, and another 40 percent are subject to controls on use (30). In the Soviet Union, all 791 million hectares of closed forests, which are publicly owned, reportedly have management plans. (See Table 5.3.)

Nevertheless, management problems persist in developed countries. Fire, insects, and disease still damage up to one quarter of the estimated annual increment in temperate forests. Air pollution and acid precipitation stunt growth rates and increase tree mortality in the United States, Sweden, Federal Republic of Germany, Finland, Poland, East Germany, and Hungary. (See Part III, Chapter 12, "Multiple Pollutants and Forest Decline.") Furthermore, some mixed forests in developed countries have been converted to plantations of commercially valuable coniferous species at the expense of wildlife habitat, the production of non-wood products (e.g., berries, nuts, etc.), soil fertility, and watershed protection.

**Figure 5.2 Changes in Forest Areas in Europe, 1954-84**




**Sources:**
1. U.N. Food and Agriculture Organization (FAO), *1955 Production Yearbook* (FAO, Rome, 1955).
2. Economic Commission for Europe (ECE)/Food and Agriculture Organization (FAO), *The Forest Resources of the ECE Region* (ECE, Geneva, 1985).

In developing countries, comparatively less forestland is managed. According to UNEP and the FAO (31), only five countries in Africa and four in Asia have significant areas of "intensively managed" forests. In 1960, harvesting regulations, working plans, and silvicultural treatments were conducted on 4–4.5 million hectares of closed forest in ten African countries, and management plans were prepared for another 6 million hectares. Today less than 2 million hectares, or barely 1 percent, of productive forests in Africa remain managed. Three quarters of them are in Ghana and Uganda, where political and economic turmoil undermine long-term management. Small areas (50–70,000 hectares) are under management in Kenya and Sudan. Working plans prepared for Cameroon and Gabon in recent years have yet to be implemented.

As in Africa, Latin America's managed forests have declined sharply—from 2.4 million hectares to 522,000 hectares—since the early 1960s. Management plans prepared for forests in Peru, Brazil, Belize, Paraguay, and Guatemala have not been implemented. Only in Nicaragua, Cuba, and Trinidad and Tobago and in small experimental forests in Costa Rica, El Salvador, Suriname, and Colombia are intensive forest-management practices used.

In Asia, the area of managed forests has increased slightly since the early 1960s from 37.3 to 39.7 million hectares. However, 80 percent of Asia's managed forests are in India, where 32.3 million hectares of forestlands were managed in 1964 and where about the same amount is managed today. Significant areas are also managed in Burma, Malaysia, and Bangladesh. In Pakistan and some other Asian countries, selective felling, periodic thinning, and occasional timber-stand improvement are practiced. Management plans prepared for 3 million hectares in the Philippines and 360,000 hectares in Indonesia in the early 1960s have not yet been implemented.

As for productive closed tropical forests, only 42 million out of 886 million hectares, or less than 5 percent of the global total, are currently managed (32). The reasons are a lack of political commitment in the face of pressure to convert these lands into farmland and pasture, the mistaken perception that economic returns from alternative land uses are always higher, and limited experience with tropical silviculture (33).

## Protected Forest Areas

Over the past century, forest areas—mostly in the tropics—comprised some 65 percent of all the lands set aside for scientific study, fish and wildlife management, watershed protection, pasture, recreation, and various combinations of these uses. (See Table 5.4.)

According to the International Union for Conservation of Nature and Natural Resources (IUCN), by 1985 the area of protected tropical humid forests stood at 39.1 million hectares distributed among 280 reserves and protected areas—up from 23.1 million in 1974 (34). The area of tropical forests legally reserved in parks and other areas where industrial wood production is prohibited was 85.7 million hectares (4.4 percent) of the forested areas of 76 tropical countries. The proportion of protected forest land is lowest in tropical America and highest in Africa, where large expanses of woodland are included in national parks. Tropical Asia has the highest proportion of protected closed forest (5.8 percent), tropical America the lowest (2.1 percent). (See Table 5.5.)

In the developing world, many of these legally protected and reserved lands are still threatened by poaching, illegal timber harvesting, wildfires, and encroachment. At the same time, many threatened forest types have yet to be protected in parks and preserves—among them are the Malagasy thorn forest, the Sri Lankan rainforest, the Burman rainforest, and the Chilean Araucaria forests. Tropical forest areas in particular need of protection include Madagascar's eastern forests, the southeast Atlantic coastal forests of Brazil, the Choco region of Colombia, and the remaining forest in Costa Rica, Nicaragua, and Panama (35).

Although the world total of protected lands doubled between 1970 and 1980, the amount of forestland reserved or protected in the developed countries has held steady in recent years (36). Some 66 million hectares, including nearly 20 percent of forestlands, have been set aside in the United States as part of the National Forest System (37). An additional 32 million hectares (38) are protected as national parks. Europe's closed forests include over 1.9 million hectares of national parks, and the total area of wooded land managed for protective functions rather than wood production or recreation amounts to 33 million hectares (or 23 percent) of all closed forests (39). The Soviet Union has designated 20 million hectares of its closed forests as national parks, and an additional 286 million hectares are managed as protected forests.

### Table 5.3 Management of Closed Forests

*(thousands of hectares)*

| Region/Country | Total Area of Closed Forest[a] | Area of Productive Closed Forest[b] | Area under Management Plans, 1963 | Area under Management Plans, 1983 |
|---|---|---|---|---|
| Europe | 145,486 | 133,304 | 93,010 | 83,484 |
| Soviet Union | 791,600 | 534,500 | 299,965 | 791,600 |
| United States | 195,256 | 189,961 | 84,378 | 102,362 |
| Tropical Asia | 305,510 | 200,989 | 37,370 | 39,790 |
| Tropical Africa | 216,634 | 163,033 | 10,610 | 1,735 |
| Central America & Caribbean | 110,895 | 74,726 | 913 | 522 |
| Tropical South America | 567,760 | 446,925 | 1,531 | 0 |
| **World Total[b]** | **2,333,141** | **1,743,438** | **527,777** | **1,019,493** |

**Notes:**
a. Table does not include data on open forests in the regions listed; the forest areas of China, Canada, and other countries in temperate Asia, Africa, and Latin America are also excluded.
b. Closed forest that is suitable for industrial wood production (i.e., not commercial timberland).

**Sources:**
1. Data for tropical regions are from U.N. Food and Agriculture Organization (FAO), 1981, Reference 44, Tables 1c and 1d; FAO, 1981, Reference 49, Tables 1c and 1d; and FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981), Tables 1c and 1d, pp. 42–43.
2. Data for Europe and the Soviet Union are from: Economic Commission for Europe (ECE)/FAO, 1985, Reference 6, pp. 19–20.
3. Data for the United States are from the U.S. Forest Service, 1980, Reference 1, p. 366.
4. Data on area under management plans for 1963 are from: FAO, 1966, Reference 28.
5. Data on area under management plans for 1983 are from FAO, Reference 44, Tables 1c and 1d; FAO, 1982, Reference 49, Tables 1c and 1d; FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981), Tables 1c and 1d, pp. 42–43; and ECE/FAO, Reference 6, Table 2.3.
6. Data for United States are estimated from commercial forestland in tree farms or owned by the U.S. Forest Service, Bureau of Land Management, state forest agencies, and forest industries. See U.S Forest Service, 1980, Reference 1.

### Table 5.4 Distribution of Protected Forested Areas by Biomes and Biogeographical Realms, 1985[a]

| | Number of Protected Areas | Extent of Protected Area (millions hectares) |
|---|---|---|
| **Forested Biomes[b]** | | |
| Tropical Humid Forests | 280 | 39.1 |
| Subtropical and Temperate Rainforests and Woodlands | 275 | 22.4 |
| Tropical Dry or Deciduous Forests or Woodlands | 582 | 65.5 |
| Evergreen Sclerophyllous Forests, Scrub, or Woodlands | 475 | 12.0 |
| Temperate Broadleaf Forests or Woodlands | 484 | 11.5 |
| Temperate Needle-Leaf Forests or Woodlands | 173 | 38.8 |
| Total | 2,269 | 189.3 |
| **Forested Realms[b]** | | |
| Tropical Realms (Neotropical, Afrotropical, Indomalayan) | 883 | 106.3 |
| Temperate Realms (Nearctic, Palaearctic, Australian) | 1,386 | 83.0 |
| Total | 2,269 | 189.3 |
| Protected Forest Area as Percent of World Total[c] | 65 | 44 |

**Notes:**
a. Includes all national parks and equivalent protected areas. Does not include game management areas, forest reserves managed for timber production, or forests managed for watershed protection.
b. Biomes are large and climatically uniform environments, each with its characteristic vegetation types. Biogeographical realms are geographical regions of the earth's surface, as defined by Udvardy.
c. While breakdown does not show desert, tundra, grassland, mountain, lake, and island biomes, these groups are included in the world total.

**Source:** International Union for Conservation of Nature and Natural Resources (IUCN), 1985, Reference 36.

## Reforestation and Forest Renewal

By 1980, 14.5 million hectares of forest land were being reforested or renewed worldwide every year (40). China currently leads the world in reforestation, planting annually more than five times the total area planted in all other developing countries. By 1965, after years of dramatic decline in China's forest area, the country was planting about 1–3 million hectares of trees each year; and by 1983–84, 13.2 million hectares had been planted.

According to official statistics, the Soviet Union had planted 11 million hectares by the early 1960s, and annual reforestation amounted to 4.5 million in 1980. However, the success rate of these plantations is not well documented. Large areas are also planted each year in the United States (1.8 million hectares per year), Canada (720,000 hectares per year), and Japan (240,000 hectares per year). Both North and South Korea plant over 150,000 hectares per year. The only other developing countries planting large areas are Brazil (346,000 hectares per year), Indonesia (187,000 hectares per year), and India (120,000 hectares per year). However, Chile (50,000 hectares per year), the Philippines (42,000 hectares per year), Argentina (38,000 hectares per year), and six other tropical countries are planting 10–50,000 hectares per year. Tropical developing countries (excluding China) annually plant 1.1 million hectares—roughly what Europe plants but less than 10 percent of the world total. Most developing countries plant 10–20 times less than what is needed to offset forest losses and meet increased demands for forest products.

As the investment costs of plantation establishment increase, the genetic quality of the planting stock has received more attention. Tree improvement, breeding, and tissue culture are being used increasingly in a number of countries to improve both the quality and quantity of wood produced from plantations. Yields from eucalyptus plantations in Brazil increased from about 22 cubic meters per hectare per year in the late 1960s to more than 60 cubic meters per hectare per year on experimental plots in 1981.

## PRODUCTION AND TRADE OF FOREST PRODUCTS

Globally, the amount of wood harvested, or "produced," increased from 1.8 to 3.0 billion cubic meters per year between 1963 and 1983 (41). Most of the increase occurred in the developing countries as demand for fuelwood, sawnwood, wood-based panels, and paper rose. Similarly, total industrial wood removals declined slightly in developed countries but increased 40 percent in developing countries. Globally, increases in the harvesting of fuelwood accounted for 83 percent of the total increase in roundwood removals over the past ten years. (See Figure 5.3.)

The value of trade in forest products increased more rapidly in the 1970s than wood removals, thanks to more efficient and complete utilization of wood and to large increases in the manufacture and trade of paper and wood-based panels. From 1973 to 1983, the value of both forest product exports and imports increased by 113 percent. Slower growth rates in trade in recent years probably reflect the general economic slowdown and many developing countries' inability to import or export more forest products.

World trade in forest products now exceeds $100 billion annually, with $82 billion traded among the developed countries. Ten developed countries account for 65 percent of the total value of imports and exports. After important shifts in the last decade among net importers and exporters, Japan, the United Kingdom, Germany, Italy, and France still dominate imports, while net U.S. imports have become significant for the first time. Imports by China, Mexico, Venezuela, Argentina, Egypt, and Nigeria have also risen. Canada, Sweden, and Finland are still the major net exporters of forest products, but Malaysia has now surpassed the Soviet Union as the fourth largest net exporter. Brazil, Chile, Australia, and New Zealand have become more important exporters, while Gabon, Ivory Coast, and the Philippines have declined in importance. (See Table 5.6.)

### Fuelwood Production

In the mid 1940s, global production of fuelwood and charcoal was 634 million cubic meters, or about 52 percent of total roundwood production. Over the next 15 years, industrial wood production increased more rapidly than fuelwood production, and the share of fuelwood in total roundwood production steadily declined by the late 1950s to a low of 41 percent. But since then increased demand in developing countries has driven fuelwood and charcoal use up to 54 percent of total roundwood production. Indeed, though industrial roundwood production has nearly tripled over the past 35 years, fuelwood production increased even more. (See Table 5.7.)

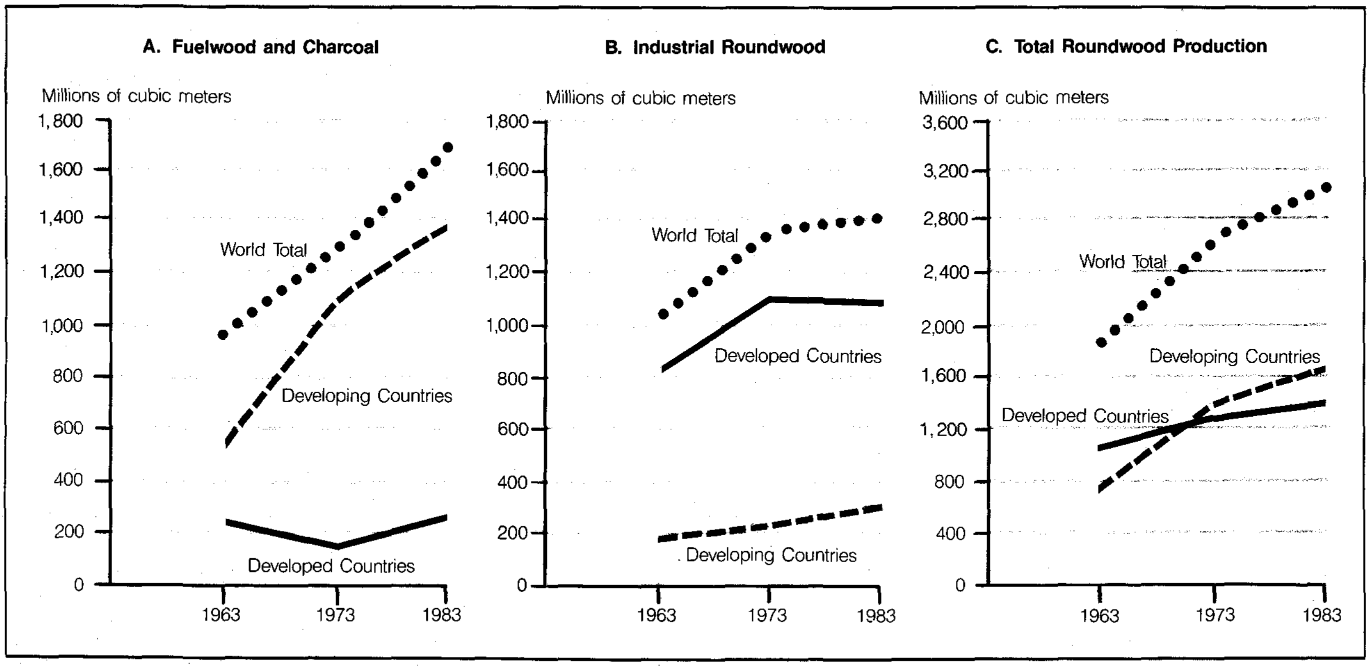
In the developing world, 13 nations—the densely populated Asian countries of India, China, Indonesia, Bangladesh, Burma, Thailand, and the Philippines and the African countries of Nigeria, Tanzania, Sudan, Kenya,

**Table 5.5 Protected Forests, 1980**

| Region/Country[a] | Total Forests (million hectares) Closed | Open | Total | Protected Forests[b] (million hectares) Closed | Open | Total | Percent of Area in Protected Forests Closed | Open | Total |
|---|---|---|---|---|---|---|---|---|---|
| Tropical Africa | 217 | 486 | 703 | 9.3 | 42.0 | 51.3 | 4.3 | 8.6 | 7.3 |
| Tropical America | 679 | 217 | 896 | 14.1 | 2.1 | 16.2 | 2.1 | 1.0 | 1.8 |
| Tropical Asia | 305 | 31 | 336 | 17.6 | 0.6 | 18.2 | 5.8 | 1.9 | 5.4 |
| **Subtotal—76 Tropical Countries** | **1,201** | **734** | **1,935** | **41.0** | **44.7** | **85.7** | **3.4** | **6.1** | **4.4** |
| Europe | 146 | 35 | 181 | 1.9 | 20.4 | 22.3 | 1.3 | 58.3 | 12.3 |
| USSR | 792 | 138 | 930 | 20.0 | 138.0 | 158.0 | 2.5 | 100.0 | 17.0 |
| North America | 459 | 275 | 734 | 36.1 | NA | 36.1 | 7.9 | X | 4.9 |
| **Subtotal—ECE Region** | **1,397** | **448** | **1,845** | **58.0** | **158.4** | **216.4** | **4.2** | **35.4** | **11.7** |
| **Total** | **2,598** | **1,182** | **3,780** | **99.0** | **203.1** | **302.1** | **3.8** | **17.2** | **8.0** |

X = *not available*; NA = *not applicable*
**Notes:**
a. For tropical areas, includes natural parks, biosphere reserves, protected forests, and all other forest areas where industrial wood production is not authorized; does not include gazetted forest reserves where timber harvesting can be authorized. For the U.N. Economic Commission for Europe (ECE) countries, includes closed forest areas, designated national parks, and protected areas of open forests.
b. Does not include China, North Africa, temperate South America, South Africa, Near East, and Oceania.
**Sources:**
1. For tropical areas: U.N. Food and Agriculture Organization (FAO), 1982, Reference 12.
2. For all other areas: ECE/FAO, 1985, Reference 6.

**Figure 5.3 Trends in Wood Production, 1973–83**




**Note:** "Production" is wood removed through harvesting, not actual growth or annual increment of trees in forests.
**Sources:**
1. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1972-1983* (FAO, Rome, 1985), pp. 64–65; 78–79; 96–97.
2. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1963* (FAO, Rome, 1964).

Zaire, and Ethiopia—together consume more than 70 percent of the total global fuelwood. Brazil, Colombia, and Mexico are also major consumers. Between 1973 and 1983, fuelwood production increased 35 percent or more in Nigeria, Tanzania, Kenya, Uganda, Guatemala, El Salvador, and Nicaragua.

Fuelwood consumption has remained high in most developing countries because fuelwood is a versatile, mostly free source of household energy. (See Chapter 7, "Energy.") Today, 20 countries in Africa, 12 in Asia, and 7 in Latin America have less than 1.5 hectares of forestland per capita and consume 80 percent or more of total wood production as fuelwood.

**Table 5.6 The World's Major Importers and Exporters of Forest Products, 1983**
*(millions of U.S. dollars)*

| Country | Exports (1983) | Imports (1983) | Net Trade |
|---|---|---|---|
| Canada | 10,240 | 841 | 9,399 |
| Sweden | 4,713 | 433 | 4,280 |
| Finland | 4,161 | 305 | 3,856 |
| Malaysia | 2,175 | 213 | 1,962 |
| USSR | 2,557 | 965 | 1,592 |
| Indonesia | 976 | 209 | 767 |
| Brazil | 823 | 150 | 673 |
| Austria | 128 | 563 | −435 |
| Belgium-Luxembourg | 851 | 1,353 | −502 |
| China | 519 | 1,565 | −1,046 |
| France | 1,263 | 2,532 | −1,269 |
| Netherlands | 428 | 2,038 | −1,610 |
| Italy | 519 | 2,914 | −2,395 |
| Germany, Federal Republic of | 2,227 | 4,881 | −2,654 |
| United States | 5,651 | 8,986 | −3,335 |
| United Kingdom | 586 | 5,163 | −4,577 |
| Japan | 734 | 6,064 | −5,330 |

**Source:** U.N. Food and Agriculture Organization (FAO), 1985, Reference 41, pp. 333-355.

Nearly 1.5 billion people in 63 countries, or about 60 percent of the people who depend on fuelwood as their principal source of energy for cooking and heating, are cutting wood faster than it can grow back. Fuelwood depletion is most serious in arid and semi-arid areas, where regrowth of shrubs and savanna woodlands is slow, and in cooler, mountainous areas, where the forest cover cannot rapidly recover from steady harvests of fuelwood. Nearly 100 million people in 22 countries (including 16 in Africa) cannot meet their minimum needs even by overcutting remaining forests. At present consumption rates, the estimated fuelwood deficit will double by the year 2000—the equivalent of 56 percent of current production in all developing countries. (See Table 5.8.)

The burden of collecting fuelwood and other biomass fuels has fallen mainly upon women and children, who must spend up to 300 workdays per year gathering each household's fuel. Where fuelwood is short, people often have no alternative but to burn grass, small twigs, bark, dried dung, crop residues, etc., even though such practices can contribute to soil erosion and reduce crop yields. In Nepal, diverting manure from the fields to the cookstove depresses grain yields by 15 percent (42). In Ethiopia, the dung that is used as household fuel has a fertilizer value of about $123 million per year and could increase grain harvests by 1–1.5 million metric tons annually (43).

In some areas, forest depletion has prompted tree planting, especially of multipurpose tree species. Eucalyptus poles are now being produced from planted seedlings by smallholders in Gujarat State in India,

**Table 5.7 Production of Fuelwood and Charcoal among Major Consuming Countries**

| Country | 1973 (millions of m³) | 1983 (millions of m³) | Increase (Decrease) | Percent Change | Fuelwood as Percent of Total Roundwood Production 1981-83 | Forest Area 1980 (hectares/person) |
|---|---|---|---|---|---|---|
| Nigeria | 56.8 | 78.4 | 21.6 | 38 | 91 | 0.2 |
| Tanzania | 28.4 | 38.7 | 10.3 | 36 | 97 | 2.3 |
| Kenya | 18.8 | 27.9 | 9.1 | 48 | 95 | 0.2 |
| Sudan | 27.7 | 36.4 | 8.7 | 31 | 96 | 2.7 |
| Zaire | 21.8 | 28.8 | 7 | 32 | 92 | 6.2 |
| Uganda | 18.2 | 24.7 | 6.5 | 36 | 94 | 0.5 |
| Ethiopia | 22.7 | 27.9 | 5.2 | 23 | 95 | 0.9 |
| **Africa Subtotal** | **312.4** | **414.4** | **102** | **33** | **88** | **1.6** |
| India | 173.2 | 212.6 | 39.4 | 23 | 91 | 0.1 |
| China | 134.4 | 154.6 | 20.2 | 15 | 68 | 0.2 |
| Indonesia | 95.5 | 114.2 | 18.7 | 20 | 90 | 0.8 |
| Thailand | 28.5 | 36.2 | 7.7 | 27 | 89 | 0.4 |
| Bangladesh | 23.7 | 31.1 | 7.4 | 31 | 97 | 0.3 |
| Philippines | 21.8 | 28.5 | 6.7 | 31 | 79 | 0.3 |
| **Asia and Oceania Subtotal** | **605.1** | **720.0** | **114.9** | **19** | **77** | **0.3** |
| Brazil | 127.3 | 162.6 | 35.3 | 28 | 73 | 4.6 |
| Mexico | 9.9 | 13.3 | 3.4 | 34 | 67 | 0.7 |
| Colombia | 11.2 | 13.9 | 2.7 | 24 | 83 | 2.0 |
| Guatemala | 4.9 | 6.6 | 1.7 | 35 | 97 | 0.6 |
| El Salvador | 3.2 | 4.4 | 1.2 | 38 | 97 | 0.03 |
| **Latin America Subtotal** | **197.1** | **253.5** | **56.4** | **29** | **73** | **2.7** |
| United States | 17.3 | 101.9 | 84.6 | 489 | 24 | 1.3 |
| Canada | 3.5 | 5.5 | 2 | 57 | 4 | 18.1 |
| **North America Subtotal** | **20.8** | **107.4** | **84.8** | **546** | **19** | **2.9** |
| Sweden | 2.5 | 4.4 | 1.9 | 76 | 9 | 3.4 |
| Italy | 3.1 | 4.1 | 1 | 32 | 48 | 0.1 |
| France | 10.6 | 10.4 | –0.2 | –2 | 27 | 0.3 |
| USSR | 83.5 | 83.3 | –0.2 | 0 | 23 | 3.5 |
| **Europe-USSR Subtotal** | **158.9** | **245.5** | **86.6** | **54** | **20** | **1.5** |
| **World Total** | **1,273.6** | **1,632.9** | **359.3** | **28** | **54** | **1.0** |

**Note:** U.N. Food and Agriculture Organization (FAO) statistics on fuelwood were incomplete prior to 1980, when new information became available as a result of a survey of fuelwood supplies in developing countries. Current "production" (or consumption) figures for fuelwood and charcoal may be somewhat high, as fuelwood has become scarce or unavailable in many areas, and principal consumers such as rural households in developing countries have been forced to substitute other fuels.
**Source:** FAO, 1985, Reference 41, pp. 78-79.

farmers in Haiti are planting trees to produce charcoal as a cash crop, and considerable supplies of fuelwood and poles are now produced in hedgerows and fallowed fields in Kenya and Rwanda. Home gardens also supply some family fuelwood needs in Sri Lanka, Bangladesh, and Indonesia (44). In the plains area of China, where 63 percent of the peasant households lacked firewood from four to six months of the year, the area of forests has been increased from 1.1 percent to 6.1 percent since 1949, and fuelwood scarcities have eased as a result. Most of the trees have been planted along rural roads and waterways, in farmland shelterbelts, and around homes, or they have been intercropped in fields (45).

## Industrial Wood Production

Worldwide, industrial wood production amounted to 1.4 billion cubic meters in 1983, or 46 percent of total roundwood production, which is an increase of only 5 percent over global production in 1973. Over half the world's production of industrial wood is from the United States, Canada, and the Soviet Union. Other important producers that are increasing industrial wood production include Brazil, Paraguay, China, Malaysia, India, Nigeria, Zimbabwe, and South Africa. As a group, developing countries increased industrial wood production by 40 percent in 1973–83, to 89 million cubic meters.

Over the past decade, paper consumption increased about 2 percent each year in the developed countries. Today, the developing countries—three quarters of the world's population—consume less than one fifth of the world's paper, though this share is growing more rapidly (5.5 percent per annum) than in developed countries, as literacy, incomes, and population increase. Between 1970 and 1980, the developing countries' share of paper production rose from 7.8 percent to 12.4 percent of the world total; at the same time, their share of paper and paperboard consumption increased from 11 to 16 percent of the total.

Along with pulp and paper, logs for sawnwood and veneer are an important part of industrial roundwood production. The global annual production of hardwood sawlogs has hovered around 240 million cubic meters over the past decade; small production decreases in Europe, the Soviet Union, and North America have been offset by gains in developing countries, which have increased their share of global production from 47 percent to 56 percent since 1973. Production of hardwood sawlogs is dominated by eight developing countries and five developed countries that together produce 73 percent of the global production.

Increased domestic consumption and processing, along with legislated reductions in exports in some countries, have also contributed to declines in hardwood exports. Only Malaysia and Papua New Guinea have significantly increased exports of hardwood logs over the past decade. Exports from Africa declined from 8.3 to 4.8 million

## Table 5.8 Fuelwood Deficits by Region, 1980 and 2000

| Fuelwood Situation | Region | Populations Involved and Fuelwood Deficit in 1980 | Countries Mainly Concerned[d] |
|---|---|---|---|
| **Acute Scarcity**[a] | Africa | 13 million people 6 million $m^3$ | Burkina Faso, Cape Verde, Chad, Djibouti, Mali, Mauritania, Niger, Sudan, Kenya, Ethiopia, Somalia, Botswana, Namibia |
| Arid and semi-arid areas | Asia | 9.5 million people 3.6 million $m^3$ | Afghanistan, Pakistan |
| | Latin America | 6.8 million people 3.5 million $m^3$ | Chile, Peru |
| Mountainous areas | Africa | 36 million people 40 million $m^3$ | Burundi, Rwanda, Lesotho, Swaziland |
| | Asia | 29 million people 34 million $m^3$ | Nepal |
| | Latin America | 2 million people 2 million $m^3$ | Bolivia, Peru |
| | Total | 96.3 million people 89.1 million $m^3$ | 23 countries |
| **Deficit**[b] | Africa | 131 million people 66 million $m^3$ | Cameroon, Congo, Zaire, Malawi, Kenya, Madagascar, Uganda, Tanzania, Gambia, Guinea, Benin, Togo, Senegal, Sierra Leone, Nigeria, Mozambique |
| Areas with rapidly increasing population and agriculture | Asia | 288 million people 75 million $m^3$ | India, Nepal, Pakistan |
| | Latin America | 143 million people 36 million $m^3$ | Brazil, Colombia, Peru, Cuba, Dominican Republic, Guatemala, Mexico, Trinidad and Tobago |
| Densely populated lowlands | Asia | 412 million people 120 million $m^3$ | Bangladesh, India, Sri Lanka, Thailand, Indonesia (Java), Philippines, Vietnam |
| | Latin America | 9 million people 6 million $m^3$ | El Salvador, Haiti, Jamaica |
| | Total | 983 million people 303 million $m^3$ | 37 countries |
| **Prospective Deficit**[c] | Africa | (in year 2000: 175 million people facing a 40 million $m^3$ deficit) | Ghana, Ivory Coast, Central African Republic, Angola, Zimbabwe, Guinea-Bissau |
| | Asia | (in year 2000: 239 million people facing a 50 million $m^3$ deficit) | Burma, India, Indonesia, Philippines, Vietnam |
| | Latin America | (in year 2000: 50 million people facing substantial degradation of fuelwood supplies) | Ecuador, Paraguay, Uruguay, Venezuela |
| | Total | 464 million people | 15 countries |
| **Surplus Potential for Wood-Based Energy** | Africa | Surplus potential 50 milllion $m^3$ | Cameroon, Congo, Equatorial Guinea, Angola, Zaire, Central African Republic |
| Low population tropical forest area | Asia | Surplus potential 200 million $m^3$ | Bhutan, Laos, Democratic Kampuchea, Indonesia (except Java) |
| | Latin America | Surplus potential 200 million $m^3$ | Amazon Basin |

**Notes:**
a. Acute scarcity: available supplies of fuelwood are insufficient to meet minimum requirements, even with overcutting.
b. Deficit: fuelwood supplies are being consumed faster than they are replenished by natural regeneration and forest growth.
c. Prospective deficit: fuelwood supplies will be in a deficit situation by the year 2000, if present trends continue.
d. Data not available for China.
**Source:** Adapted from U.N. Food and Agriculture Organization (FAO), "Fuelwood and Energy" Priority Action Program in Tropical Forestry (FAO Forestry Department, draft working paper, Rome, 1985).

cubic meters and exports from Latin America declined from 525,000 to 47,000 cubic meters between 1973 and 1983. The decline in both log production and exports has been particularly notable in Thailand, Indonesia, Philippines, Ivory Coast, Liberia, Congo, and Colombia. In Brazil, Cameroon, and Nigeria, increased local consumption has overshadowed production increases. Indonesia, Malaysia, Philippines, and Cameroon have increased domestic processing of sawlogs and exports of sawnwood.

In January 1985, Indonesia introduced a total ban on unprocessed log exports. Among the major producers that still export a large proportion of sawlog production are Papua New Guinea and Gabon, which export over 90 percent of their log production, and Liberia, Malaysia, and Ivory Coast, where log exports account for 50–60 percent of total sawlog production. Malaysia, Papua New Guinea, Philippines, Ivory Coast, and Gabon together account for 84 percent of the world's exports of hardwood logs.

Although the total volume of log exports has declined from 45 to 29 million cubic meters over the past five years, the value of hardwood log exports from developing countries increased from $1.9 billion in 1973 to a high of $3.8 billion in 1979, falling to around $2.6 billion annually in the 1980s. Developing countries still account for 90 percent of the world's hardwood log exports, and 64 percent of these exports now originate in Malaysia.

## FOCUS ON: DEFORESTATION IN DEVELOPING COUNTRIES

Deforestation, perhaps the world's most pressing land use problem, commonly refers to the clearing of forest and its conversion to non-forest uses. Tropical forests provide humanity with a cornucopia of benefits. Tropical forests are living museums and laboratories that have yielded only a tiny fraction of their treasures to scientific study. Many useful chemical products essential for making medicines and pharmaceuticals originate in tropical plants. More than 50 percent of modern medicines come from the natural world, many from tropical forests, including: strychnine, ipecacuanha, reserpine, curare, and quinine.

Industrial products derived from tropical moist forests include volatile essential oils, gums, resins, latexes, and other exudates, steroids, waxes, rubber, fibers, dyes, tanning agents, turpentines, edible oils, rattans, bamboo, flavorings, spices, and pesticides.

Tropical forests protect watersheds and regulate water flow for farmers who grow food for well over 1 billion people. When upland watersheds are deforested, downstream hydropower reservoirs and irrigation systems suffer from siltation. Erosion and sedimentation of rivers cause flooding and enormous human suffering. Furthermore, rainforests are home to some 200 million people, who rely on the forests for the necessities of life. Tropical forests provide them with fruits, nuts, and honey, along with fibers and wood for building, fuelwood for cooking, lighting, and heating, and animal fodder for livestock raising.

Perhaps the most important aspect of tropical forests is their incredible array of life. During the ice ages, they served as refuges where less hardy species survived and later repopulated the temperate zones. Whereas temperate, northern forests are unlikely to contain more than 10–15 tree species per hectare, a single hectare of Amazon rainforest has been known to contain up to 230 tree species. Panama, for example, has as many plant species as all of Europe combined. And peninsular Malaysia has 7,900 species of flowering plants, compared with the United Kingdom's total of 1,430 species in twice the area. If tropical forests continue to be destroyed at current rates, the resulting ecosystem degradation could even generate local or regional climatic changes, with as yet unknown consequences.

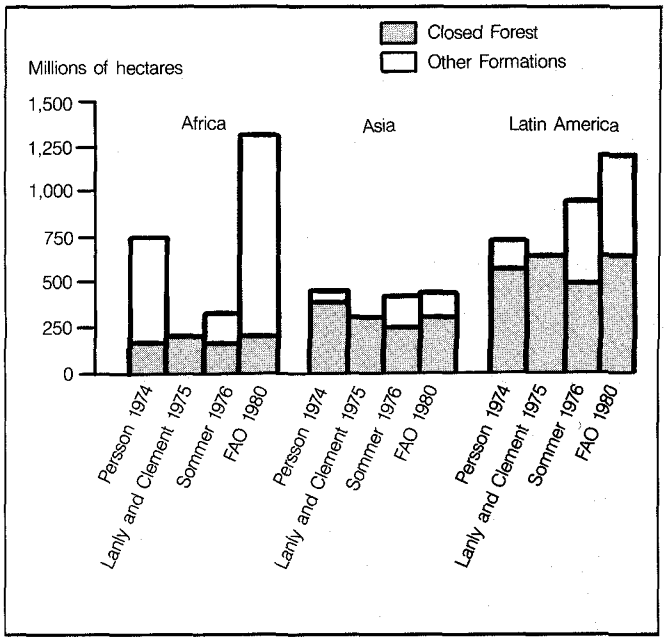
Unfortunately, scientists cannot pinpoint the extent of deforestation since the accuracy of assessments of global forest area over the past several decades has varied considerably (46). (See Figure 5.4.) In the early 1980s, average annual deforestation of open tree formations in tropical countries was estimated to be about 3.8 million hectares, though even this estimate includes only the area of forested land that is cleared and converted to non-forest uses, and doesn't take the effects of fuelwood collection, and other influences into account. (See Table 5.9.)

These uncertainties aside, the FAO has projected that 150 million hectares, or 12 percent, of the remaining closed tropical forests and roughly 76 million hectares of open tropical woodlands will be deforested by the year 2000 (47). Over the past ten years, 1.3 million hectares of closed broadleaved forests were cleared annually in Africa. Another 2.3 million hectares of open woodlands were also deforested each year in Africa between 1980 and 1985 (48). Much larger areas were degraded through harvesting for fuelwood and construction wood, cutting for fodder, grazing, fire, and drought. Conversion and degradation have been particularly severe in semi-arid West and East Africa, where supplies of fuelwood, poles, forage, and other secondary forest products that rural households need have dwindled. In all, African countries account for 62 percent of the deforestation of the world's open tropical forests and woodlands.

Over half of the forest loss (55 percent) occurred in the West African countries of Ivory Coast, Nigeria, Liberia, Guinea, and Ghana, where the rate of forest loss is seven times the world average. Each year, 290,000 hectares of closed forest in the Ivory Coast and 300,000 hectares in Nigeria are deforested. Annually, 50–100 million cubic meters of quality logs, or three to six times the annual production of sawlog and veneer logs in these countries, are lost through clearing and burning, along with wood that could be recovered and converted to charcoal or used as fuelwood (49). Most of the forest loss in East Africa is occurring in Madagascar, one of the richest tropical reservoirs of biological diversity. In Ethiopia, the forested area has shrunk from 16 percent of the land area in the 1950s to 4 percent in the 1970s, leaving the country increasingly vulnerable to droughts and floods.

In tropical Asia, 1.8 million hectares of closed forest were deforested every year between 1976 and 1980. Deforestation in this region results primarily from encroachment by lowland villages and shifting agriculture and from planned transmigration and resettlement. Especially large areas have been deforested in Indonesia, Thailand, Malaysia, Philippines, India, Burma, and Laos. Asia's highest rates of deforestation are in Nepal (3.9 percent) and Thailand (2.4 percent), where population size is large relative to the size of remaining closed forest areas. The forest area of the Himalayan watershed has declined by 40 percent over the past 30 years, contributing to shortages of food, fuel, and wood in the uplands and to floods and siltation in the lowlands.

**Figure 5.4 Estimates of Tropical Forest Area in Africa, Asia, and Latin America**




**Sources:**
1. Adapted from J.C. Allen and D.F. Barnes, "Deforestation, Wood Energy and Development," (Resources for the Future, Inc., unpublished, Washington, D.C., 1982).
2. For 1974 estimates: R. Persson, *World Forest Resources: Review of the World's Forest Resources in the Early 1970s*, Research Notes No. 17 (Department of Forest Survey, Royal College of Forestry, Stockholm, 1974).
3. For 1975 estimates: J.P. Lanly and J. Clement, "Present and Future Natural Forest and Plantation Areas in the Tropics," *Unasylva*, Vol. 31, No. 123, pp. 12–20 (1979).
4. For 1976 estimates: A. Sommer, "Attempt at an Assessment of the World's Tropical Moist Forest," *Unasylva*, Vol. 28, Nos. 112 and 113, pp. 5–24 (1976).
5. For 1980 estimates: U.N. Food and Agriculture Organization (FAO), *Tropical Forest Resources*, FAO Forestry Paper No. 30 (FAO, Rome, 1982).

**Table 5.9 Average Annual Deforestation of Tropical Forests by Forest Type and by Region, 1981–85[a]**
*(thousands of hectares)*

| Region | Productive Closed Forests: Undisturbed Area | Undisturbed Percent[b] | Logged Area | Logged Percent[b] | Unproductive Closed Forests Area | Unproductive Closed Forests Percent[b] | All Closed Forests Area | All Closed Forests Percent[b] | Open Forests Area | Open Forests Percent[b] | Total Deforestation Area | Total Deforestation Percent[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tropical America | 1,299 | (0.29) | 1,867 | (2.80) | 1,173 | (0.75) | 4,339 | (0.64) | 1,272 | (0.59) | 5,611 | (0.63) |
| Brazil | 80 | (0.03) | 1,030 | (8.58) | 370 | (0.65) | 1,480 | (0.41) | X | X | X | X |
| Tropical Africa | 226 | (0.19) | 1,032 | (2.41) | 73 | (0.14) | 1,331 | (0.61) | 2,345 | (0.48) | 3,676 | (0.52) |
| Zaire | 155 | (0.19) | 25 | (6.58) | 2 | (0.008) | 182 | (0.17) | X | X | X | X |
| Tropical Asia | 395 | (0.39) | 1,278 | (2.14) | 153 | (0.15) | 1,826 | (0.60) | 190 | (0.61) | 2,016 | (0.60) |
| Indonesia | X | X | 600 | (1.73) | X | X | 600 | (0.53) | X | X | X | X |
| **Total** | **1,920** | **(0.28)** | **4,177** | **(1.98)** | **1,399** | **(0.45)** | **7,496** | **(0.62)** | **3,807** | **(0.52)** | **11,303** | **(0.58)** |

X = not available
**Notes:**
a. Tropical forest includes broadleaved, coniferous, and bamboo forests.
b. Calculated as percent of forest area in 1980.
**Sources:**
1. U.N. Food and Agriculture Organization (FAO), 1982, Reference 12.
2. U.S. Congress, Office of Technology Assessment, 1984, Reference 2.

Estimates of China's forested area vary widely. Land use data indicate that forest and woodlands increased in area from 115 to 128 million hectares between 1975 and 1982 (50). According to other FAO data, 170 million hectares were wooded in China in 1980, including 125 million hectares of closed forest and another 45 million hectares of other wooded land (51). However, despite the world's most ambitious reforestation program, it appears that fires, clearing for agriculture, uncontrolled cutting, and management failures have led to the loss of 16 million hectares of forests in five of China's most densely forested provinces since 1955. In Yunnan province, the forest cover declined from 55 percent to 30 percent of the land area between 1949 and 1975, a difference of 11 million hectares. Timber production in China has declined since 1979, and in 1972–77 some 35 million hectares of cropland (double the area affected in 1950–58) were subject to severe flooding or droughts (52).

While annual deforestation rates are predicted to level off in tropical Africa and Asia, rates were expected to increase in Latin America to over 4 million hectares per year in 1985 (53). From 1976 to 1980, 3.8 million hectares per year were cleared or converted to other uses.
Apart from Brazil, which accounts for 35 percent of the annual deforestation of closed forests in tropical America, large areas are deforested each year in Peru, Venezuela, Bolivia, Colombia, Ecuador, and Mexico. Annual deforestation rates are especially high (greater than 3 percent) in Paraguay, Costa Rica, and El Salvador (54). In Haiti, the forest cover had already been reduced to less than 10 percent of the land area by 1978, though losses continue (55).

Deforestation in tropical America has been driven by population growth, pressure to clear more land for farming, land speculation, and the development of commercial ranches. Government fiscal policies also have a strong effect. For example, squatters in Amazonia can establish proprietary claims and increase the resale value of land by clearing the forest cover. Similarly, businesses can reduce their tax obligations by investing in ranches in Amazonia (56). In Brazil, deforestation may claim close to several million hectares per year. In six Amazonian states, the deforested area increased by more than 150 percent between 1975 and 1978 to 7.3 million hectares (57). Costa Rica was two-thirds forested as recently as 1940, and only one-third forested by 1980 (58).

In Table 5.10, tropical countries are grouped according to average annual deforestation rates and the area of closed forest cleared annually. In Group I, deforestation rates are relatively high and considerable areas are affected by forest loss. In Group II, the areas of closed forest area annually cleared in most countries exceed 20,000 hectares per year, though the deforestation rate is 0.5 percent per annum or lower. Deforestation in Group I and Group II countries represents 98 percent of annual losses to closed tropical forests. In Group III, the rate of deforestation is high (over 0.6 percent), but the area affected is small (less than 20,000 hectares). In Group IV, small areas are affected and deforestation rates are generally low.

## RANGELAND RESOURCES

About one half of the earth's terrestrial surface is considered natural rangeland. It can occupy areas as diverse as the open forest of the southeastern United States, the grasslands of the Russian steppe and tundra, the deserts of the Mideast, and the sub-Saharan savanna and thorn scrub.

Strictly speaking, rangelands are wild forage-producing areas under native grasses used, among other things, for livestock, wildlife, and watershed maintenance. However, many analyses of range resources also refer to the FAO statistical category of permanant meadows and pastures, which includes more intensively managed areas (i.e., fenced, seeded, fertilized, and irrigated) that yield a controlled high productivity (such as hay fields).

### Importance of Rangelands

More than one third of the earth's land area is too dry for rainfed agriculture and these arid zones constitute most of the world's rangelands. Of these, about 2.3 billion hectares (or half the arid and semi-arid lands) are in developing countries (59). At least half of these areas may be too rocky, steep, poorly drained, or cold to farm, but they do support grasses and other forage plants. This native forage, in turn, can support livestock that is grown

## Table 5.10 Deforestation in Tropical Countries, 1981–85

| Country | Closed Forest Area, 1980 (thousand hectares) | Annual Rate of Deforestation 1981–85 (percent) | Area Deforested Annually (thousand hectares) |
|---|---|---|---|
| **Group I[a]** | | | |
| Colombia | 47351 | 1.7 | 820 |
| Mexico | 47840 | 1.2 | 595 |
| Ecuador | 14679 | 2.3 | 340 |
| Paraguay | 4100 | 4.6 | 190 |
| Nicaragua | 4508 | 2.7 | 121 |
| Guatemala | 4596 | 2.0 | 90 |
| Honduras | 3797 | 2.4 | 90 |
| Costa Rica | 1664 | 3.9 | 65 |
| Panama | 4204 | 0.9 | 36 |
| Malaysia | 21256 | 1.2 | 255 |
| Thailand | 10375 | 2.4 | 252 |
| Lao People's Dem Rep | 8520 | 1.2 | 100 |
| Philippines | 12510 | 0.7 | 91 |
| Nepal | 2128 | 3.9 | 84 |
| Vietnam | 10810 | 0.6 | 65 |
| Sri Lanka | 2782 | 2.1 | 58 |
| Nigeria | 7583 | 4.0 | 300 |
| Ivory Coast | 4907 | 5.9 | 290 |
| Madagascar | 12960 | 1.2 | 150 |
| Liberia | 2063 | 2.2 | 46 |
| Angola | 4471 | 1.0 | 44 |
| Zambia | 3390 | 1.2 | 40 |
| Guinea | 2072 | 1.7 | 36 |
| Ghana | 2471 | 0.9 | 22 |
| **Total** | **241037** | **1.7** | **4180** |
| **Group II[b]** | | | |
| Brazil | 396030 | 0.4 | 1480 |
| Peru | 70520 | 0.4 | 270 |
| Venezuela | 33075 | 0.4 | 125 |
| Bolivia | 44013 | 0.2 | 87 |
| Indonesia | 123235 | 0.5 | 600 |
| India | 72521 | 0.2 | 147 |
| Burma | 32101 | 0.3 | 105 |
| Kampuchea, Dem | 7616 | 0.3 | 25 |
| Papua New Guinea | 34447 | 0.1 | 22 |
| Zaire | 105975 | 0.2 | 182 |
| Cameroon | 18105 | 0.4 | 80 |
| Congo | 21508 | 0.1 | 22 |
| Gabon | 20690 | 0.1 | 15 |
| **Total** | **979836** | **0.3** | **3160** |
| **Group III[c]** | | | |
| El Salvador | 155 | 3.2 | 5 |
| Jamaica | 195 | 1.0 | 2 |
| Haiti | 58 | 3.4 | 2 |
| Kenya | 2605 | 0.7 | 19 |
| Guinea-Bissau | 664 | 2.6 | 17 |
| Mozambique | 1,189 | 0.8 | 10 |
| Uganda | 879 | 1.1 | 10 |
| Brunei | 325 | 2.2 | 7 |
| Rwanda | 412 | 0.7 | 3 |
| Benin | 47 | 2.1 | 1 |
| **Total** | **6529** | **1.2** | **76** |
| **Group IV[d]** | | | |
| Belize | 1385 | 0.6 | 9 |
| Dominican Republic | 685 | 0.6 | 4 |
| Cuba | 3025 | 0.1 | 2 |
| Trinidad and Tobago | 368 | 0.3 | 1 |
| Bangladesh | 2207 | 0.4 | 8 |
| Pakistan | 3785 | 0.2 | 7 |
| Bhutan | 2170 | 0.1 | 2 |
| Tanzania | 2658 | 0.4 | 10 |
| Ethiopia | 5332 | 0.2 | 8 |
| Sierra Leone | 798 | 0.8 | 6 |
| Central African Republic | 3595 | 0.1 | 5 |
| Somalia | 1650 | 0.2 | 4 |
| Sudan | 2532 | 0.2 | 4 |
| Equatorial Guinea | 1295 | 0.2 | 3 |
| Togo | 304 | 0.7 | 2 |
| **Total** | **31789** | **0.2** | **75** |

**Notes:**
a. *Higher than average rate of deforestation and large areas deforested.*
b. Relatively low rates of deforestation but large areas deforested.
c. High rates of deforestation and small areas of remaining forest.
d. Low or moderate rates of deforestation and small areas affected.

**Sources:**
1. U.N. *Food and Agriculture Organization* (FAO), 1981, *Reference* 44.
2. FAO, 1981, Reference 49.
3. FAO, *Los Recursos Forestales de la America Tropical* (FAO, Rome, 1981).
4. FAO/U.N. Economic Commission for Europe, 1985, Reference 10.

for meat and other products and wildlife, which provides a reservoir of genetic diversity as well as a major source of protein and income in many developing countries.

The world's livestock herd amounts to more than 2.3 billion head of cattle and sheep, and over 700 million head of other types of livestock. Globally, the total investment in domestic livestock is on the order of $400 billion (60). In developing countries, livestock is a common means of accumulating capital. These assets can reproduce and are readily liquidated if cash is needed. Worldwide, exports of fresh and frozen meat, milk, wool, and live animals represented 12 percent of total agricultural exports in 1983. In many African countries livestock products account for more than half of total agricultural exports. (See Table 5.11.)

Although hay from tame pastures, feed grains, concentrates, and byproducts of milling and food processing now supply a significant fraction of livestock rations (61), forage from native rangelands and pasture still accounts for 80–85 percent of the feed of ruminant livestock (62); in developing countries, it supplies more than 95 percent of total feed. In the United States, native rangelands contribute about 16 percent of the feed of sheep and cattle, while pasture grazing provides 55 percent. The remaining 29 percent is supplied by feed grains and concentrates (63).

Rangelands support an estimated 30–40 million nomadic and pastoral people, including 16 percent of the population of Afghanistan and large numbers in Mauritania, Chad, Mali, Sudan, Somalia, Ethiopia, Kenya, India, and China (64). Many more, involved in animal husbandry, depend at least partly on rangelands. The economic contribution of pastoralists to national economies can be essential. For example, livestock products account for 67 percent of Somalia's agricultural exports, although nomads represent only 10 percent of the total population of the country.

In developing countries, livestock supplies half of the non-human energy used in agriculture, as well as dung needed to maintain soil fertility (65). Without livestock, developing countries would have to spend an additional $40 billion on mechanical power for agriculture and $6 billion on fertilizers. Draught animals are needed not only for plowing, but also for transportation and pumping of irrigation water. In both Asia and Africa, livestock is more important than tractors as a source of power on farms.

Rangelands are also sources of fuelwood, fencing materials, roof thatch, edible fruits and leaves, tannins, gums, and other products rural communities need. The wildlife that roams rangelands provides 50 percent of the

**Table 5.11 Value of Livestock Products in Agricultural Exports, 1983**
*(billions of U.S. dollars)*

| Region | Meat Exports | Milk Exports | Live Animal Exports (Cattle, Sheep, Goats) | Wool Exports | Subtotal Livestock Exports | Total Agricultural Production Exports | Livestock Products as Percent of Total Agricultural Exports |
|---|---|---|---|---|---|---|---|
| Africa | 0.1 | — | 0.6 | 0.2 | 0.9 | 10.9 | 8 |
| Asia | 0.8 | 0.07 | 0.4 | 0.05 | 1.3 | 27.5 | 5 |
| South America | 1.4 | 0.02 | 0.2 | 0.2 | 1.8 | 19.4 | 9 |
| North America | 1.8 | 0.40 | 0.4 | — | 2.6 | 56.3 | 5 |
| Europe | 8.9 | 3.60 | 2.1 | 0.1 | 14.8 | 80.2 | 18 |
| Oceania | 2.8 | 0.40 | 0.2 | 1.7 | 5.1 | 10.9 | 47 |
| Total Developed Countries | 13.4 | 4.90 | 2.5 | 2.0 | 22.5 | 141.8 | 16 |
| Total Developing Countries | 2.5 | 0.10 | 1.3 | 0.2 | 4.1 | 65.7 | 6 |
| **Total World** | **15.9** | **4.60** | **2.8** | **2.6** | **25.6** | **207.5** | **12** |

— = negligible value
**Note:** Numbers have been rounded to nearest 0.1 billion.
**Source:** Adapted from U.N. Food and Agriculture Organization (FAO), *FAO Trade Yearbook*, Vol. 37 (FAO, Rome, 1984).

meat consumed in Botswana and forms the basis of tourism, the second most important source of foreign exchange in Kenya.

## Extent of Rangelands

There is no comprehensive global assessment of the extent of rangelands. Even defining "rangeland" is difficult. The term describes both land use and cover. The most complete data available—from the FAO—are organized by type of vegetation; thus, the total extent of rangeland must be calculated by adding parts of various FAO categories. The best available estimate for the world as a whole and for the major regions is presented in Table 5.12. It adds the area of permanent pasture, 3.16 billion hectares, to the 1.37 billion hectares of open forests and about half the FAO's "other land" category, 2.19 billion hectares of desert, tundra, and scrub. The total amount of rangelands by this estimate is 6.7 billion hectares or about 51 percent of the total land area of the world.

## Condition of Rangelands

Range condition is an estimate of how close the range is to its natural potential cover, or climax vegetation, given a site's soil, rainfall, and other characteristics (66). Range condition is good if the forage production rate is 80 percent or more of site potential; poor if the forage production rate is 20 percent or less of site potential (67). The trend indicates whether the forage production rate is improving, deteriorating, or relatively stable.

Data on rangeland condition are sparse or non-existent for much of the world. A lack of standardization in classification and analysis compounds the problem. However, a number of national and sub-national studies conducted over the past ten years indicate conditions and trends in some key countries.

Xerification, or a drying of the soil, leads to the phenomenon called "desertification." Xerification most commonly results from overstocking, or overuse of a portion of the available forage by homogeneous herds of cattle, for example. It also results from use of rangeland for dry land agriculture. Heavy grazing by cattle selectively removes the most palatable perennial native grasses called "decreasers" and results in patches of bare soil, increases of less productive and nutritious annual grasses called "increasers" or invasion by foreign species called "exotics." Desertification also results in less litter and more compaction of the soil. Then the infrequent but heavy rains characteristic of arid zones do not have a chance to percolate into the soil, recharging underground aquifers and providing moisture to the plants. Instead, the rains carry the topsoil away.

**Table 5.12 Distribution of the World's Pastures and Rangelands 1955–83**

| | Area of Permanent Pasture[a] (million hectares) | | | Permanent Pasture As Percent of Land Area | Open Forests[b] | Other Land[c] | Estimated Total Area Range and Pasture[d] (million hectares) | Rangeland As Percent of Total Land Area |
|---|---|---|---|---|---|---|---|---|
| | 1955 | 1975 | 1983 | 1983 | 1980 (million hectares) | 1983 (million hectares) | | |
| North America (United States and Canada) | 277 | 265 | 265 | 14 | 275 | 746 | 913 | 50 |
| Europe | 83 | 88 | 86 | 18 | 22 | 91 | 153 | 33 |
| USSR | 124 | 374 | 373 | 17 | 137 | 702 | 861 | 39 |
| Central America (inclusive & Caribbean) | 79 | 94 | 95 | 32 | 0.3 | 99 | 145 | 48 |
| South America | 330 | 446 | 456 | 26 | 248 | 230 | 819 | 47 |
| Africa | 615 | 785 | 778 | 26 | 508 | 1,317 | 1,945 | 65 |
| Asia (except China) | 279 | 372 | 359 | 21 | 61 | 602 | 721 | 41 |
| China | 194 | 286 | 286 | 31 | 45 | 415 | 538 | 58 |
| Oceania | 377 | 472 | 460 | 55 | 76 | 182 | 627 | 75 |
| **World Total[e]** | **2,358** | **3,181** | **3,157** | **24** | **1,372** | **4,384** | **6,721** | **51** |

**Notes:**
a. Includes permanent meadows and pastures and land that has been used for five years or more for the production of herbaceous forage crops, either cultivated or wild.
b. Includes wooded land with a grass understory beneath the open canopy. Livestock and wildlife browse on both the leaves and twigs of the trees and on the grasses.
c. "Other land" is a residual category defined by the U.N. Food and Agriculture Organization (FAO) in its *Production Yearbook*. About one-third of this land is so dry it lacks plant cover. However, a significant percentage of this land may be grazed seasonally or in years of heavy rainfall. Half of this category is counted in the estimated total area of range and pasture.
d. Sum of areas of permanent pasture (1983), open forest (1980), and 50 percent of "other land" (1983).
e. Numbers may not add up to totals because of rounding.
**Sources:**
1. Data on "permanent pasture" and "other land" are from U.N. Food and Organization (FAO), *1983 Production Yearbook*, Vol. 38 (FAO, Rome, 1985), Table 1, pp. 47–48; and FAO, *1955 Production Yearbook* (FAO, Rome, 1955).
2. Data on open forests and other wooded land are from FAO, 1985, Reference 10.

Where grain cropping intrudes into rangelands, nutrients are lost at a rate 30 times that of a properly stocked range (69). In many areas, replacing lost phosphorous, potassium, and nitrogen with commercial fertilizers is far too costly, so that nutrient impoverishment contributes further to desertification.

In many desertification-prone countries, range development efforts have concentrated on raising productivity by improving animal health, developing new sources of water, introducing new breeds, or increasing the production of forage crops and intensively managed pastures. However, the lack of attention to the condition of the range itself, together with its increasing use, often results in large-scale deterioration.

### *Africa*

In Africa, rangelands are concentrated in the Sahel in West Africa and in the countries bordering the semi-arid areas of East and South Africa. Seventy-five percent of Botswana is permanent pasture, and about 65 percent of Zambia, South Africa, and Lesotho is permanent pasture. Forty-five to 60 percent of the land area of Somalia, Mozambique, and Madagascar is considered native rangeland. Summaries of studies of nine African countries are shown in Table 5.13.

In the north African countries of Morocco, Tunisia, Algeria, Libya, and Egypt, forage production from rangelands has been declining, and overgrazing has caused the rangeland to deteriorate in many areas. However, a tropical rangeland often shows much higher recovery rates than those found in temperate zones. In Tunisia, temporarily protecting the range from grazing has increased forage production from 128 kilograms per hectare (kg/ha) to 1,244 kg/ha in just four years.

In Zambia, where livestock numbers are ten times greater than the carrying capacity of the available rangelands, the range is rapidly deteriorating. Large areas of Zimbabwe's rangelands are also overgrazed or bare, including 8 million hectares of former tribal trust lands.

Range conditions in the drier, northern part of Cameroon are generally poorer than in the wetter, southern Guinean zones, where livestock numbers are limited by trypanosomiasis. In the north, heavy overgrazing, frequent fires, and periodic droughts have caused annual grasses, unpalatable shrubs, or bare ground to replace the original perennial grasses and leguminous trees. A recent assessment of 36 range-management units indicated that 7 out of 16 units in the north were in poor or very poor condition, while 6 out of 13 units in the south were in excellent or good condition. The remaining 7 units were in fair condition (68). Dwindling productivity in northeastern Uganda's range also stems mainly from overstocking. Range resources in northern Kenya are reportedly in poor condition, although other ranges in the south are in fair condition. The condition of rangelands in both Sudan and Somalia is also reportedly deteriorating as unpalatable shrubs or annuals overtake perennials.

In the Sahel region of West Africa, the worst rangeland conditions are found near year-round water supplies and where pastoral and agricultural land uses overlap. (See Box 5.1.)

Of 19 countries in the Sudano-Sahelian zone, only Guinea and Guinea-Bissau report stable conditions; eight countries report some increase and nine report a significant increase in desertification. (See Part IV, "Forests and Rangelands," Table 6.3.)

### *Near East*

Many ranges in the Near East are in poor condition. Unpalatable shrubs have invaded Iraq's steppe rangelands. In Syria's interior steppes and arid deserts, the original plant community has been replaced by species of little value to people or animals. Yemen's rangelands are in poor condition and deteriorating, and "erosion pavement" is now common in Jordan's rangelands. The alpine meadows of Iraq, where the harsh winters preclude year-round use, and the deserts and mountains of Oman, where herd sizes have been decreasing and the use of fodder crops increasing, are still in relatively good condition. In southern Saudi Arabia, the number of unpalatable species has recently increased, and 60 percent of all range management units are in poor or fair condition, compared to 40 percent in good or excellent conditon.

Rangeland condition in much of Afghanistan is fair or good, but declining as a result of overgrazing, especially around Kandahar and Herat and along the major migration routes. In Pakistan, most rangelands are in poor condition, producing only 10–15 percent of their potential and losing important species of palatable forage plants, including the woody *Acacia*. Iran's rangelands are already the most depleted in the region, and their condition is deteriorating.

### *Europe*

Only 18 percent of Europe's land area is permanent pasture, but these lands receive adequate rainfall, are intensively managed, and are highly productive. The area of permanent pasture in Africa is six times greater than Europe's, but Europe supports 75 percent more cattle and sheep than Africa, and the value of Europe's livestock product exports is 16 times greater than Africa's. The productivity of Europe's pasturelands has increased beyond 500 animal production units (APU) per hectare per year, compared to less than 20 APU/hectare/year in most developing countries.

### *United States and Australia*

Since 1936 the rangeland conditions in the United States have been regularly assessed. Overall conditions have gradually improved. For example, the area of nonfederal rangeland in excellent and good condition has increased from about 16–20 percent to a current level of 34–36 percent. (See Figure 5.5.)

Out of 347 million hectares of rangelands in the United States, roughly 207 million hectares (about 60 percent) are currently in good or fair condition. The remainder, some 40 percent, are in poor or very poor condition. Large areas of Alaskan rangeland, which are in good condition because they have not been exploited for long periods, tend to skew the national averages upward. For the lower 48 states, 46 percent of the rangelands are in

# Table 5.13 Rangeland Conditions in Selected African Countries

| Country/Locality | Size of Area | Range Condition | Range Trend | Causes |
|---|---|---|---|---|
| **Cameroon**<br>**Country-wide** | 8,300,000 hectares | Original perennial grassland and acacia types mostly replaced by annuals and unpalatable shrubs | Not specified, but potential for livestock development (based on forage yields) for 16 resource management units as follows: 3—very low; 4—low; 7—medium; 2—high or very high | Many years of heavy grazing and frequent burning |
| **Northern Sector** | 7,000,000 hectares | | | Recent (about 1975) drought |
| Sudano-Sahel region (Acacia grasslands and steppes-Sahel; dry and moist woodlands—Sudanian types) | | "Almost denuded state" in many areas | | |
| Guinea-Congolian region (south of Garoua) | | Range in better condition than Sudano-Sahelian types | Potential of 13 resource management units: 7—medium; 4—high; 2 very high | Use of range reosurces limited by tsetse fly infestations |
| **Southern Sector**<br>Adamaoua Plateau and other localized areas | About 1,300,000 hectares | Quality of range generally better than in northern sector | Not specified, but probably stable | More rainfall<br>Tsetse fly limitations |
| **Sudan** | 56,000,000 hectares ("permanent pasture")<br>24,000,000 hectares ("grasslands") | Range deteriorating and desertification accelerating | Apparently continuing downward | Increasing livestock numbers 5 to 18 million head cattle during last 30 years)<br>Cultivation of marginal lands<br>Woodcutting and uprooting of shrubs for fuelwood |
| **Somalia** | 29,000,000 hectares | Overgrazed—perennial grasses replaced by annuals and in some cases by unpalatable shrubs | Deterioration accelerating | Overgrazing (increased demand for meat & livestock products) |
| **Kenya**<br>Rendille management area (Northeast Kenya) | 13,249 square kilometers | Based on field measurements of soil stability, composition plants species, percent bare ground and litter cover, state of soil erosion:<br>Percent area of 22 management units:<br>"Range" / "Woodland" (Browse)<br>2.4% Exc. 2.4%<br>1.5 Good 5.1<br>77.1 Fair 70.1<br>10.6 Poor 13.6<br>1.7 Very Poor 6.5<br>6.6 NA 2.2 | Time trend data not available, but predominance of fair and poor condition indicates a serious state of rangeland degradation | Since some of the area had not been used for a long time due to tribal conflicts, the cause for the degraded condition is not certain; two hypotheses:<br>— Previous excessive grazing completely suppressed preferred herbaceous plants, promoting growth of less desired species<br>— Current vegetation is a climate climax type resultant from sporadic and low rainfall |
| **Uganda**<br>Northeast region | 5,000,000 hectares | | | |
| Entire Karamoia District | 316,390 hectares | Perennial grasses replaced by plants with lower nutrient requirements, therefore less value as animal feed | Irreversible erosion | Majority of these Savanna grazing lands beyond zone of trypanosomiasis and livestock populations have increased rapidly during past decades (accounting for much of the country-wide increase) |
| Most of Acholi District | Semi-arid range | Reduction of ground cover<br>Majority of grassland areas are four disclimax created by fire and grazing (and would return to dry forest if these factors eliminated) | | Overgrazing (feeding and trampling) |
| **Morocco** | 12,141,000 hectares rangelands, country-wide | Reduced forage production<br>Expanding desertification | Deteriorating (e.g., degradation of Stipa Tenacissima "Alfa grassland" estimated at 10,000 hectares/year) | Overstocking<br>Expanding dryland agriculture<br>Uprooting of woody shrubs for fuel |

| Consequences/Projections | Remedial Activities | Source |
|---|---|---|
| | **Northern Sector** | |
| Severely degraded areas unlikely to recover without protection | Plans for protection/recovery of degraded rangelands include creation of controlled grazing reserves (320 potential areas already identified): the extremely degraded Chari Delta near Lake Chao and Diamare plain suggested as pilot areas | 1 |
| Pressure on open area grazing lands can be partially alleviated with tsetse control programs or livestock prophylaxis | Reseeding and water development efforts, combined with rotational grazing systems, proposed to mitigate range destruction around the limited number of dry season waterholes | |
| | **Southern Sector** | |
| Cattle increasing at 1–2% per year, but increase expected to cause forage degradation except around human population centers | Pilot project for livestock management in tsetse areas planned for locality south of Benoue River | |
| A total of 75–80 million hectares (ha) considered suitable for agriculture, but only 24 million ha currently used for grazing, 7 million used for farming | Not specified | 2 |
| The rangeland is the greatest natural resource of the country | A 1975 FAO/UNDP project to initiate range management education in the university was successfully established, but was terminated once project assistance ended<br>Currently foreign aided range development program in operation | 3 |
| It is projected that significant improvements can be realized | Detailed and adaptive management plan, including grazing pressure and distribution recommendations, animal husbandry and disease control improvements, and development of a viable marketing system | 4 |
| Erosion | Few studies examining the extent of devegetation caused by livestock<br>Problems have not been addressed sufficiently by the administration<br>Improved pasture management research conducted by veterinary trainers at Entebbe (primarily for dairy cattle) | 5 |
| Increased soil erosion<br>Decline in natural grassland area<br>Increases in animal production only possible at the additional deterioration of range forage | Planting of forage shrubs:<br>— Opuntia cactus, plantations can yield 10–50 metric tons green matter/hectares/year<br>— Saltbush (Atriplex)<br>New management practices including:<br>— Control of grazing pressures<br>— Rotation and deferred grazing schemes<br>Houz afforestation project to protect soils and improve pasture | 6 |

(continued on next page)

good or fair condition, with only 15 percent in good condition. Rangeland types in relatively poor condition include desert and annual grasslands, Texas savanna, southwestern shrub-steppe, and chapparal-mountain shrub.

In Australia, as in the United States, rangelands that were degraded in 1900 have gradually improved in recent decades in most areas. Overstocking, especially during dry periods, and the explosive growth in the population of introduced rabbits contributed significantly to the earlier degradation of Australia's rangelands. Currently, some 13 percent of all rangeland is affected by soil erosion and the degradation of natural vegetation.

## DEVELOPMENT ASSISTANCE AND RANGE MANAGEMENT

The impacts of large-scale, international development assistance projects on tropical rangelands warrant close examination. Aid projects have generally attempted to raise the economic productivity of range use systems by promoting the use of homogeneous herds of cattle. Cattle can be marketed, and exported, in order to generate the foreign exchange needed to service external debt. However, large herds of cattle are not always well-suited to tropical range environments.

Confronted with a daunting record of failure in range management projects, assistance agencies are now taking a new look at the traditional pastoralist systems. Instead of large homogeneous herds, pastoralists generally graze small mixed herds that make use of the full spectrum of available vegetation. Camels eat the higher strata of woody vegetation, goats eat the lower strata, sheep consume herbaceous plants and grasses and can be selective with their prehensile lips; cattle are less selective grazers.

Moreover, pastoralists generally sell off the sick and weak animals, in contrast to western tradition. The very large herds, encouraged by assistance projects, overstress the ecosystem. When drought strikes, the entire system can collapse. When that happens, there is a longer term effect because of the disparity between the amount of time it takes for cattle herds to rebound and the amount of time required for rangelands to recover: cattle can be restocked within a few years, but it takes much longer to rejuvenate degraded rangeland, especially when soil—which forms at the snail's rate of one inch per 500 years—is eroded.

Range specialists identify the key underlying causes of these well-intentioned but repeated failures as the export of inappropriate technology and a remarkable failure to view the range community of plants, animals, and people as an integrated system. Until these failings are corrected, the sorry record of assistance-aided range "disasters" will likely continue.

## THE DIFFICULTIES OF RANGE ASSESSMENTS

National-level evaluations of rangeland conditions often obscure important local variations (e.g., over 40 million hectares of U.S. range are in very poor condition although

## Table 5.13 Rangeland Conditions in Selected African Countries

| Country/Locality | Size of Area | Range Condition | Range Trend | Causes |
|---|---|---|---|---|
| **Morocco** | | | | |
| **Tunisia** | 3,142,000 hectares | Degraded<br>Rangelands estimated to be producing at 1/2 of potential (optimistic estimate) | Presumed to be continually deteriorating | Uncontrolled grazing; fuelwood cutting<br>Long history of misuse—traditional nomadism has been disrupted since colonial times (10 years) and the emphasis on sedentarization has concentrated grazing pressure<br>Stocking rates estimated to 3–8 times higher than ideal |
| **Zambia**<br>Country-wide<br>Upper Zambezi (Western Province)<br>Kafue River locality<br>Eastern Province | 35,000,000 hectares | Deteriorated; severe cover depletion | Not specified, but in view of excessive (tenfold) stocking rates, trend presumed down | Overgrazing—average stocking rate for entire country is 0.32–0.45 hectare/livestock unit (10–15 times higher than recommended)<br>Surveys show rangeland degradation from overgrazing not perceived as a problem by rural inhabitants |
| **Zimbabwe**<br>Tribal Trust Lands | 16,161,000 hectares | Approximately 50 percent of this area in very poor condition (based on 1960 survey) | Most recent survey made in 1960; situation has certainly deteriorated | Overgrazing from increased livestock population (+119 percent 1964–77) |
| Buffalo Ranch Farm | 20,000 hectares | | | Stocking rate management: |
| — Cattle section | 12,000 hectares | Good condition (37.8% cover; 30% litter; 28% utilization) | Apparently stable, possibly improving | — 8.5 hectares/livestock unit |
| — Game section | 8,000 hectares | Fair condition (30% cover; 20% litter; 43% utilization) | Apparently stable | — 8.0 hectares/livestock unit equivalent (455 kg) |

**Sources:**
1. U.N. Food and Agriculture Organization (FAO), *1983 Production Yearbook*, Vol. 37 (FAO, Rome, 1984); and University of Arizona, *Draft Environmental Profile on United Republic of Cameroon* (Office of Arid Lands Studies, University of Arizona, Tucson, 1981), pp. 21–28, 32–35, and 47–48.
2. Op. cit. 1, FAO; and A.W. A. El Moursi, *Ecological Management of Arid and Semi-Arid Rangelands* (EMASAR—Phase II), Vol. VII, Near East (FAO, Rome, 1978), pp. 29–31; FAO, "Regional Study on Rainfed Agriculture and Agro-Climatic Inventory of Eleven Countries in the Near East Region," in *World Soil Resources Report* (FAO, Rome, 1982).
3. Op. cit. 2, El Moursi, pp. 23–24.
4. United Nations Education, Scientific and Cultural Organization (UNESCO), *Integrated Resource Assessment and Management Plan for Western District, Marsabit, Kenya*, IPAL Technical Report No. A-6, Part I and II (UNESCO, W.J. Lusigi, Ed., Paris, 1984).
5. Op. cit. 1, FAO; and U.S. Man and the Biosphere (USMAB), *Draft Environmental Profile of Uganda* (Office of Arid Land Studies, University of Arizona, Tucson, 1982), pp. 36, 48–52, 85–87, 92, and 122–123.
6. U.S. Man and the Biosphere (USMAB), *Draft Environmental Report on Morocco* (Office of Arid Lands Studies, University of Arizona, revised, Tucson, 1981), pp. 11–16.
7. Op. cit. 1, FAO; and University of Arizona, *Draft Environmental Profile on Tunisia* (Office of Arid Lands Studies, University of Arizona, Tucson, 1980), pp. 13–14, 16–18, 25, 33–34.
8. Op. cit. 1, FAO; and University of Arizona, *Draft Environmental Profile of Zambia* (Office of Arid Lands Studies, University of Arizona, Tucson, 1982), pp. iii, 70–71 and 97–102.
9. University of Arizona, *Draft Environmental Profile of Zimbabwe* (Office of Land Studies, University of Arizona, Tucson, 1982), pp. iii, 48–51, 55–64, 89–95.

overall, its condition is fair to good). However, they do reveal that areas of critical concern are found on many continents and in many biogeographic realms, at both high and low altitudes, and not surprisingly, are concentrated in countries heavily dependent on this resource for their economic well-being.

Of the 32 countries or regions analyzed in Figure 5.6, 14 are faced with such critically deteriorating range conditions that they fall within the high risk category; 9 areas (including the lower 48 states of the United States) are in the moderate risk category; and 9 (including Alaska) are in the low risk category.

No single cause can be found for the problems of countries whose range resources are at risk. Great differences in culture, climate, ecology, and economics make this resource a particularly site-specific challenge to manage. More than for most resource systems, data are less readily extrapolated from region to region and solutions found to work in one area may not work in another. Research is badly needed to develop a series of well defined management strategies that could prove more widely applicable than current approaches.

## RECENT DEVELOPMENTS

### INVESTMENT IN FORESTRY: PRIORITIES AND NEEDS

Over the past decade, less than 1 percent of the assistance provided by the international development banks has been allocated to forestry. (See Table 5.14.) Similarly, only 5 percent of the budget of the FAO is allocated to its Forestry Division (70). Although it increased in the late 1970s and early 1980s, investment in forestry in develop-

| Consequences/Projections | Remedial Activities | Source |
|---|---|---|
| | Dakahala pasture improvement (beginning with tree shelter-belts later to plant shrubs suitable for grazing) 72,000 hectares area 1948–68, combined with forage planting<br>Establish national seed production center (200 ha)<br>Establish national committee for pasture land (planning to develop 25,000 ha grazing land each year) | |
| Traditional nomadism allowed periods for plant regrowth<br>Forage production in a protected plot increased from 128 kg/ha after 1 year to 1,244 kg/ha after 4 years (including a good rainy year) | 1958 law limiting goat raising<br>1960 and 1966 laws regulating exploitation of esparto grass (used for both paper and grazing)<br>— Other range management activities not specified | 7 |
| Soil erosion widespread | Not specified and figures on the magnitude of the problem not readily available | 8 |
| Seriously deteriorated forage resource base<br>Severe droughts have caused high annual mortality in some areas, decreasing grazing pressure and allowing range to recover some | Some successful range management schemes introduced at a local level (details and locations not provided)<br>None required | 9 |
| Assumed sustainable production | None required | |
| Assumed sustainable production | | |

ing countries still does not reflect forests' crucial role in sustaining food production, creating employment and income, providing essential raw materials and goods, and generating scarce foreign exchange.

For many reasons, forests in many developing and developed countries are now stressed, and policy changes and increased investment are needed urgently to head off serious productivity declines. Fortunately, given these needs, numerous recent developments in forestry offer encouragement.

Since 1982, the FAO has been preparing an action program for tropical forests. The detailed five-part action program covers fuelwood and wood energy, land use, forest industrial development, conservation of tropical forest ecosystems, and institution strengthening. Simultaneously, a task force convened in 1984 by the World Resources Institute (WRI), in cooperation with the World Bank and the United Nations Development Program (UNEP) reviewed the causes and remedies of low levels of investment in forest conservation and development in *Tropical Forests: A Call for Action* (71). The task force concluded that many proven responses to land misuse and deforestation exist and that the lack of political and, consequently, financial will to support them stems from a poor understanding of the consequences of failing to act. According to WRI, an estimated $8 billion in public and private investment is needed between 1987 and 1991. Half that amount could be provided by doubling development assistance, with the remainder provided by national governments and the private sector. The proposed action plan spells out a five-year investment program and includes case studies of successful projects models and specific investment profiles for 56 countries.

There has been a recent surge of activity among nongovernmental organizations (NGOs) engaged in forestry-related activities (72). A 1981 directory of 1,720 NGOs active in development assistance lists only seven engaged in forestry (73). Since then, afforestation projects have proliferated, not just in forestry programs, but in those to combat desertification, erosion, siltation, fuelwood shortages, and rural hunger.

Nationally, the thrust and impact of NGO activities defy generalization, though several examples illustrate the spectrum of efforts. In Haiti, dozens of local NGOs participating in a reforestation program coordinated through three U.S.-based international NGOs, and funded by the United States Agency for International Development (AID) have planted more than 10 million seedlings since 1981. In India, the number of village tree-planting groups has been estimated to exceed 40,000. In Indonesia, Senegal, and some other countries, NGOs involved in forestry and other resource conservation and development projects are so numerous that national consortia have been organized to facilitate coordination and communication among members. The Kenya Energy Non-Governmental Organization (KENGO) has 50 organizational members and 120 other associated private voluntary agencies. Such groups help produce and distribute seedlings, increase village-level participation, and push for legislative reform—key elements in successful reforestation programs.

## INTERNATIONAL TROPICAL TIMBER AGREEMENT

After nine years of negotiations, an international agreement on the production and use of industrial wood from tropical countries was adopted in 1983 and ratified in March 1985 by the U.N. Conference on Tropical Timber, organized under the auspices of the U.N. Conference on Trade and Development (UNCTAD). Known as the International Tropical Timber Agreement (ITTA), its objectives are to promote international trade in industrial wood from tropical countries and to help tropical timber-producing and timber-consuming countries cooperate to allow management of tropical forests. In addition to regulating trade in tropical timber, ITTA also encourages research and development in five areas: improved forest management and wood utilization, further processing of tropical timber in producer countries, expanded reforestation and forest management, improved marketing and distribution of tropical timber exports, and increased study of trading patterns in tropical timber. No action under this new agreement has yet been taken.

## Box 5.1 Primary Production in the Sahel—Implications for Range Resource Management

Ecological studies conducted between 1976 and 1981 by the "Institut d'Economie Rural" (Bamako, Mali) and the Dutch Government provide perhaps the best scientific basis for understanding the biophysical processes involved in Sahelian range forage production, the impacts of different intensities of exploitation, and the possibility of increasing forage yields. Many of the findings of this investigation are radically different from earlier understandings, and suggest a new interpretation of range management options for the Sahel. Key findings of the Primary Production in the Sahel (PPS) study (1) are:

- The productivity of the Sahelian animal husbandry system, expressed in animal protein per unit area, is at least equal to, or even better than, that of ranching in comparable zones (100–600 mm rainfall) in the United States and Australia.
- Even though nomadic and semi-nomadic pastoralists cope with their adverse environmental conditions extremely well (in terms of animal protein produced per unit area), production is often not sufficient to provide a subsistence level livelihood. Moreover, this production requires a mode of exhaustive exploitation that leads to deterioration of the environment, and thus cannot be maintained over the long-term. Animal husbandry in the Sahel needs to be rehabilitated.
- In addition to decades of cash crop production in the Sahelian countries, the food requirements of the growing human population have caused an expansion of the agricultural crop area, increased intensity in land use (e.g., shortened fallow periods), and increased grazing pressure. These factors are causing a gradual decline in soil fertility and productivity.
- On average, only 75 percent of the rainfall infiltrates the soil; the remainder runs off. (This runoff is an important source of surface drinking water.) Overexploitation of the pasture promotes excessive runoff and results in degradation of the environment.
- In general, however, the Sahara is not advancing southward; a shortage of drinking water protects this desert border area against overexploitation. On the other hand, overexploitation is causing increasing degradation in the southern Sahel region and northern savanna areas (the Sudano-Sahelian interface zone where mixed farming is predominant).
- Poor soil quality, both chemically and physically, is a great barrier to development. Precipitation is not used in an optimal way for plant production in the Sahel since the soils are deficient in both nitrogen and phosphorus. As a consequence, in the southern Sahel, for example, only 10 percent of the annual rainfall is used by the vegetation.
- Fertilizers could increase primary production under natural rainfall as much as fivefold. However, the cost of nitrogenous fertilizers is not economic under the Sahelian animal husbandry system, nor are the treated phosphates (the rock phosphates available in some of the countries are absorbed 10–20 times more slowly by plants than are the super phosphates).
- There are many indigenous legume species in the Sahel with good nitrogen-fixing capacity, but their ability to compete against grasses, their germination strategy, the low phosphorus status of the soils, and the low rainfall limit their contribution to the productivity and quality of the pastures. The only way to improve the growth of legumes in natural rangeland is by the application of phosphates. In the Sahel region proper, the cost of this measure could be five times greater than the value of the yield. Large-scale introductions of exotic legumes are unlikely to succeed, although experimentation with species requiring less phosphorus may be warranted.
- Because of their favorable effect on the quantity and quality of available forage, fire and grazing are indispensable in the traditional pastoral grazing system. Attempts to combat degradation and decreases in productivity by banning fires and overgrazing can be successful only if solutions are found for the shortage of proteins in the forage during the dry season.
- Dryland farming in the southern Sahel and northern Sudanian savanna profits more from animal husbandry than the animals do from the crop residues under current conditions. Benefits to the animals from increased integration of these activities can be realized only if the quantity and quality of the agricultural by-products are improved by fertilization.
- The natural tree cover in the Sahel varies from 0–5 percent and is in balance with the water resources. Accordingly, afforestation has little chance of succeeding except in places where water runoff concentrates.
- Technical options exist to increase productivity in the Sahel, although they are not economically feasible under present conditions. Hence, to increase, or even maintain, the productivity of the Sahel, external funding is necesary. Millions of dollars can, however, be spent more effectively if the ecological constraints on development are better understood and incorporated into the formulation and implementation of aid programs.
- The study's results do not make it easier to formulate proposals for the accelerated development of the Sahel region. The soil is being depleted for both arable farming and animal husbandry. In many areas this is unavoidable and there is probably no alternative. Social and economic conditions in the region are such that modern methods of production (such as the use of fertilizer) are unlikely to succeed in the short term, and even if the situation were to change, environmental constraints preclude agricultural expansion on a large scale.
- In spite of this bleak picture, the search for new ways to promote development is vital to the Sahel. The *status quo* means continued deterioration of the environment. In some cases, it may be justified to consider investments, which from a purely economic viewpoint produce no immediate returns. These could include such measures as the creation of alternative employment opportunities and improving regional infrastructure. Subsidizing meat and grain production would have negative internal rates of return, but could improve production. Possible programs might include:

1. Growing leguminous crops with the use of phosphorous fertilizers.
2. Continued integration of dryland farming and animal husbandry, combining the use of manure and chemical fertilizers to produce better quality forage.
3. Fattening operations on a small scale in situations where fertilizers can be used economically to produce such cash crops as cotton and groundnuts with high quality by-products.

### References

1. H. Breman and P.W.J. Uithol, *The Primary Production in the Sahel (PPS) Project: A Bird's Eye View* (Center for Agrobiological Research, Wageningen, The Netherlands, 1984), pp. 5–11 and 37–41.

## CHANGING PRIORITIES IN FORESTRY RESEARCH

The 1981 Congress of the International Union of Forestry Research Organizations (IUFRO) highlighted the need for increased support of forestry research related to Third World needs (74). Since then, the priorities of forestry researchers around the world have changed dramatically. The recommendations of a recent workshop on forestry research priorities in the Asian region stressed the importance of increasing the productivity of multipurpose tree species, increasing fuelwood supplies, rehabilitating and protecting watersheds and degraded lands, and generating income and employment through forestry (75). Future IUFRO workshops will cover related issues. In 1986, a second workshop in Africa will concentrate on the research needs of the Sahel and northern Sudanian zones. Participants will examine agroforestry, natural regeneration and forest management, the selection and improvement of multipurpose tree and shrub species, the use of nitrogen-fixing woody plants, and other low-input technologies to maintain soil productivity. A third workshop in Latin America will focus on more efficient harvesting, processing, and treatment of tropical woods.

## Table 5.14 Distribution of Loans by International Development Banks, 1983

*(millions of U.S. dollars)*

| Institution | Total Annual Lending[a] | Agriculture Sector[b] | Percent of Total | Energy Sector[c] | Percent of Total | Forestry Sector[d] | Percent of Total |
|---|---|---|---|---|---|---|---|
| The World Bank | 14,477 | 3,698 | 26 | 2,818 | 20 | 83 | 0.60 |
| Inter-American Bank | 3,045 | 489 | 16 | 968 | 32 | 2 | 0.06 |
| Asian Development Bank | 1,893 | 825 | 44 | 524 | 28 | 52 | 2.70 |
| African Development Bank | 930 | 261 | 28 | 274 | 30 | 6 | 0.70 |
| **Totals** | **20,345** | **5,273** | **26** | **4,584** | **22** | **143** | **0.69** |

**Notes:**
a. Data are from 1983 Annual Reports for each agency and include loans authorized for all sectors; agriculture, forestry, industry, health, education, transportation, urban development, public utilities and energy.
b. Agriculture includes agriculture credit and rural development, agricultural research, as well as fisheries, livestock, and forestry.
c. Generally includes loans for oil, gas, coal, and power development; data for public utilities are substituted in the case of the African Development Bank, which did not report on a separate category for energy projects.
d. Does not include capital investment in pulp and paper industrial processing capacity. Data are from bank reports and personal communications.

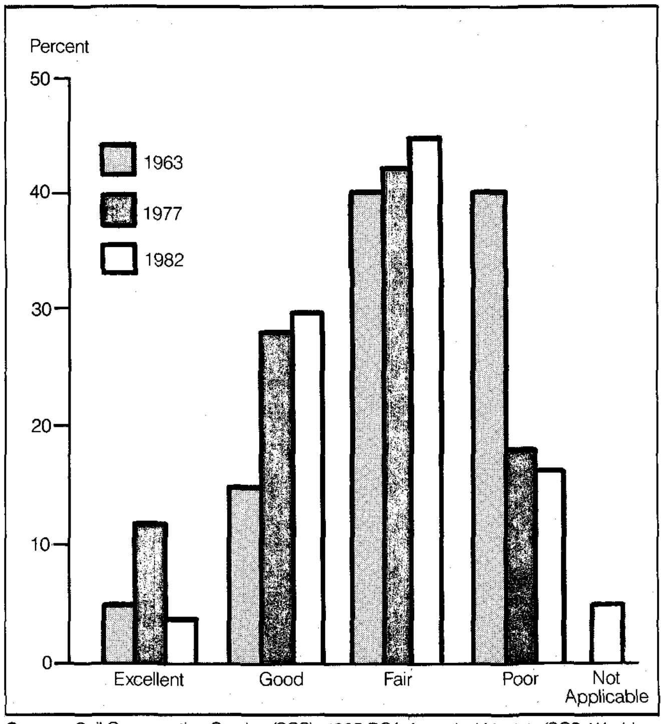
**Sources:**
1. The World Bank, *The World Bank Annual Report 1983* (The World Bank, Washington, D.C., 1983).
2. Inter-American Development Bank, *Annual Report 1983* (Inter-American Development Bank, Washington, D.C., 1983).
3. Asian Development Bank, *Annual Report 1983* (Asian Development Bank, Manila, 1983).
4. African Development Bank, *Annual Report 1983* (African Development Bank, Abidjan, Ivory Coast, 1983).

The main themes of the 1986 IUFRO World Congress are multipurpose tree species, utilization of tropical woods and related topics, air pollution's effects on forests, wood for energy, and forest resource monitoring.

Two major research efforts devoted solely to agroforestry are also under way. The International Council for Research in Agroforestry is completing a global inventory of agroforestry systems, especially in traditional land use systems in developing countries. In addition, FAO has helped establish networks of research institutions aimed at increasing knowledge and use of forest trees, food trees, and fruit-bearing species.

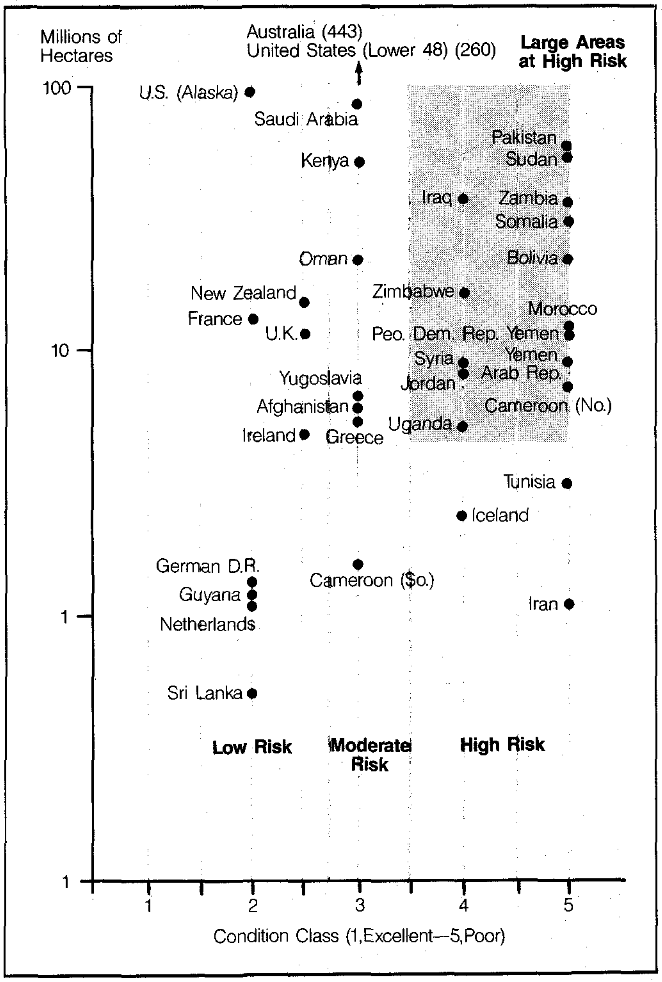
Several new journals reflect the shift to new areas of emphasis in forestry. They include the *Agroforestry Systems Journal*; the *Journal of Agriculture, Ecosystems and Environment*; and *The International Tree Crops Journal*. *New Forests*, an international journal on the biology, biotechnology, and management of afforestation and reforestation, will begin publication in 1986.

## Figure 5.5 Distribution of U.S. Nonfederal Rangeland by Condition Class, 1963, 1977, and 1982




**Source:** Soil Conservation Service (SCS), *1985 RCA Appraisal Update* (SCS, Washington, D.C., draft, 1985), p. 71.

## Figure 5.6 Global Sample of Rangeland Extent and Condition




**Note:** The high percentage of tame pasture rather than rangeland *(sensu stricto)* in European countries accounts for their very high productivity (i.e. twenty times USSR and USA) and condition.
**Source:** Compiled by World Resources Institute from various sources.

## References and Notes


1. U.S. Forest Service, *An Assessment of the Forest and Range Land Situation in the U.S.* (U.S. Department of Agriculture, Washington, D.C., 1980), p. 25. Rangeland is land having less than 10 percent cover of forest trees, on which the existing or potential natural vegetation is predominantly grasses, grass-like plants, forbs, or shrubs. Others have defined rangeland more broadly, to include all land producing native forage for animal consumption; such land is generally too dry, steep, rocky, wet, or otherwise limited for most intensive cropping uses. The second, broader definition would include land that is also classed as "open forest."
2. U.S. Congress Office of Technology Assessment, *Technologies to Sustain Tropical Forest Resources* (U.S. Congress, Washington, D.C., 1984), p. 65. *Forest area* generally includes both closed and open forests. *Closed forest* has a cover of trees sufficiently dense to prevent the development of a grass understory. *Open forest* has at least 10 percent tree cover, but enough light penetrates the tree canopy to permit the growth of grass under the trees.
   In addition to closed and open forests, *wooded land* may also include forest fallow, shrubland, and the estimated area covered by trees outside the forests. *Forest fallow* is land that has been cleared and used for shifting cultivation within the last 20 years and now supports a regrowth of woody plants. *Shrubland* has a vegetative cover dominated by shrubs (woody plants less than 7 meters high) because of either low rainfall or degradation of the tree cover.
3. R. Winterbottom, *Rwanda Integrated Forestry and Livestock Project*, Report of the Phase II Rural Forestry Preparation Mission (Food and Agriculture Organization/World Bank, Washington, D.C., 1985), p. 6.
4. B. van Gelder and P. Kerhof, *The Agroforestry Survey in Kakamega District*, Final Report, Kenya Woodfuels Development Program (KWDP) Working Paper No. 6 (KWDP, Nairobi, 1985), pp. 14–15.
5. People's Republic of China, Ministry of Forestry, *China's Forestry and Its Role in Social Development* (Ministry of Forestry, presented, World Forestry Congress, Mexico City, 1985), p. 28.
6. Economic Commission for Europe (ECE)/Food and Agriculture Organization *The Forest Resources of the ECE Region* (ECE, Geneva, 1985), Table 1.2, pp. 16–18.
7. P. Buringh, in *The World Environment 1972-1982* (M.W. Holdgate, *et al.*, Eds. United Nations Environment Program, Dublin, 1982), p. 253.
8. J.S. Olson, "Productivity of Forest Ecosystems," in *Productivity of World Ecosystems* (National Academy of Sciences, Washington, D.C., 1975), p. 41.
9. *Op. cit.* 2, p. 65. Broadleaved forests are also referred to by the "hardwood" they produce, as opposed to the "softwoods" produced in coniferous or needle-leaved forests.
10. U.N. Food and Agriculture Organization (FAO)/Economic Commission for Europe (ECE), *Forest Resources 1980* (FAO/ECE, Rome, 1985).
11. U.N. Food and Agriculture Organization (FAO), "Forestry Beyond 2000," *Unasylva*, Vol. 37, No. 147, p. 12 (1985).
12. U.N. Food and Agriculture Organization (FAO), *Tropical Forest Resources*, Forestry Paper No. 30 (FAO, Rome, 1982), Table 1f, p. 50.
13. U.N. Food and Agriculture Organization (FAO), *1983 Production Yearbook*, Vol. 37 (FAO, Rome, 1984), Table 1, p. 56.
14. *Ibid.*
15. *Op. cit.* 12, p. 50.
16. E. Matthews, "Global Vegetation and Land Use," *Journal of Climate and Applied Meteorology*, Vol. 22, pp. 474–487 (1983).
17. U.N. Food and Agriculture Organization (FAO), *Production Yearbooks*; 1950–82 (FAO, Rome, 1950–82), Table 1.
18. The net forest products import bill for the ten states of the European Economic Community increased from $9 billion to $17.5 billion between 1974 and 1980, when it represented the second largest expenditure of foreign exchange after oil.
19. F.C. Hummel, "In the Forests of the EEC," *Unasylva*, Vol. 34, No. 138, pp. 2–16 (1982).
20. *Op. cit.* 1, pp. 28–31; and Food and Agriculture Organization "Wood: World Trends and Prospects," *Unasylva*, Vol. 20, No. 80–81, Table III–A, p. 66 (1966).
21. *Op. cit.* 2, p. 65. "Unproductive" refers to forests that cannot be exploited commercially because of accessibility, topography, or other reasons. Such forests may be highly productive in an ecological sense. In the United States, such forests are termed "non-commercial."
22. *Op. cit.* 12, pp. 80 and 84.
23. J. Melillo, *et al.*, "Comparison of Two Recent Estimates of Disturbance in Tropical Forests," *Environment Conservation*, Vol. 12, No. 1, pp. 37–40 (1985).
24. *Op. cit.* 6, Table 1.3, pp. 19–20.
25. *Op.* cit. 12, pp. 12, 47, and 50. "Productive" closed forests are those in which the production of wood for industry (sawlogs, pulpwood, and other industrial wood) is possible.
26. *Op. cit.* 12, p. 47.
27. *Op. cit.* 7, p. 253.
28. U.N. Food and Agriculture Organization, "Wood: World Trends and Prospects," *Unasylva*, Vol. 20, No. 80–81, Table III–A, p. 66 (1966).
29. *Op. cit.* 12, pp. 12–13. Applicable in the case of closed productive forests that have been or will be commercially logged, the term implies that harvesting is regulated and followed by silvicultural and protection measures designed to maintain commercial productivity.
30. *Op. cit.* 10. Eighty-eight percent of the publicly owned forests have management plans, as opposed to 27 percent of the 72.5 million hectares of privately owned closed forest land in Europe. However, uses are controlled for most of the remainder of private forest lands.
31. *Op. cit.* 12, pp. 47 and 56–58.
32. *Op. cit.* 12, p. 47.
33. World Resources Institute (WRI), "Forest Management for Industrial Uses," Tropical Forests Action Plan Project (WRI, paper, Washington, D.C., 1985), pp. 23–26.
34. United Nations Environment Program (UNEP), *The World Environment 1972–1982*, M. Holdgate, *et al.*, Eds., (UNEP, Dublin, 1982), p. 234.
35. World Resources Institute, *Tropical Forests: A Call for Action*, Part I (WRI, Washington, D.C., 1985), pp. 37–38.
36. International Union for Conservation of Nature and Natural Resources (IUCN), *The United Nations List of National Parks and Protected Areas* (IUCN, Gland, Switzerland, and Cambridge, U.K., 1985).
37. *Op. cit.* 1, p. 31.
38. *Op. cit.* 6, Table 1.3., pp. 14–15. Does not include privately owned and locally protected areas.
39. *Op. cit.* 6, Table 1.4, pp. 21–22.
40. *Op. cit.* 10; and P. Wardle, Food and Agriculture Organization, Rome, 1985 (personal communication). Reforestation includes some areas of managed "natural" regeneration, reforestation of recently harvested or cleared land, and afforestation of land which has not supported a forest cover in the recent past. In most cases the area "reforested" or planted includes an unknown area of failed plantation that must be replanted in succeeding years.
41. U.N. Food and Agriculture Organization (FAO), *Yearbook of Forest Products 1972–1983* (FAO, Rome, 1985), pp. 14–15. Available statistics on wood "production" are equivalent to wood removals (amount of wood harvested) and to wood consumption but do not represent the annual increment or measured growth of trees and forests. Total roundwood production is the sum of all wood removed from forests and trees outside the forests, including fuelwood, industrial wood, and the equivalent roundwood volume of wood converted into charcoal and chips.
42. World Bank, "Economic Analysis Issues in Bank Financed Forestry Projects" (World Bank, AGR technical note, draft, November 1984), p. 54.
43. K. Newcombe, "An Economic Justification for Rural Afforestation: The Case of Ethiopia," Energy Department Paper No. 16 (World Bank, Washington, D.C., 1984), p. 16.
44. U.N. Food and Agriculture Organization (FAO), *Forest Resources of Tropical Asia* (FAO, Rome, 1981), p. 59.
45. *Op. cit.* 5, pp. 27–30.
46. J. Allen and D. Barnes, "Deforestation, Wood Energy and Development" (Resources for the Future, paper, Washington, D.C.) pp. 5–6.
47. *Op. cit.* 12, p. 101.

Photo: R. Mittermeier

48. *Op. cit.* 12, p. 84.
49. U.N. Food and Agriculture Organization (FAO)/United Nations Environment Program, *Forest Resources of Tropical Africa*, Part I (FAO, Rome, 1981), pp. 83–90.
50. *Op. cit.* 13, Table 1, p. 50.
51. *Op. cit.* 10.
52. V. Smil, "Deforestation in China," *AMBIO*, Vol. 12, No. 5, pp. 226–231 (1983).
53. *Op. cit.* 12, p. 77.
54. *Op. cit.* 12, p. 80.
55. L. Lewis and W. Coffey. "The Continuing Deforestation of Haiti," *AMBIO*, Vol. 14, No. 3, pp. 158–160 (1985).
56. P.M. Fearnside, "Human Use Systems and the Causes of Deforestation in the Brazilian Amazon," (U.N. University Conference on Climatic, Biotic and Human Interactions in the Human Tropics, presented, Sao Paulo, Brazil, February 1985), Table 1, p. 22.
57. Tucker, *et al.*, "Intensive Forest Clearing in Rondonia, Brazil, as Detected by Satellite Remote Sensing," *Remote Sensing of Environment*, Vol. 15, pp. 255–261 (1984).
58. S. Sader and A. Joyce, *Global Tropical Forest Monitoring* (unpublished paper, 1985).
59. U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture 1982* (FAO, Rome, 1983), p. 127. The limit of rainfed agriculture is assumed to be around 300–400 millimeter mean annual precipitation.
60. *Ibid.*, p. 79.
61. *Ibid.*, p. 108. Ten countries accounted for the consumption of 414 million metric tons of feed grains for livestock in 1981. This is 70 percent of the world's use of feed grains. The ten countries, in order of importance of use of feed grains, are the United States, the Soviet Union, China, Canada, France, Brazil, Japan, Poland, the Federal Republic of Germany, and Spain.
62. *Ibid.*, pp. 85, 99, and 105. Excluding pigs and poultry.
63. *Op. cit.* 1, p. 275. Grazing (range and non-range) currently supplies 64 percent of the feed consumed by beef cattle and 79 percent of the feed consumed by sheep in the United States. *op. cit.* 1, p. 289. Assuming an average of about 71 percent of the feed requirements for cattle and sheep are met by grazing, feed grains and concentrates supply about 29 percent of feed requirements. Range now supplies 22 percent of all grazing, with the remaining 78 percent supplied by non-range grazing (improved pastures, hayfields, etc.).
64. S. Sandford, *Management of Pastoral Development in the Third World* (John Wiley, New York, 1983), p. 2.
65. *Op. cit.* 59, p. 82.
66. *Op. cit.* 1, p. 253.
67. R. Dasmann, *et al.*, *Ecological Principles for Economic Development* (John Wiley, London, 1973), p. 92.
68. Excellent condition is equated with "very high potential," good with "high potential," fair with "medium potential," poor with "low," and very poor with "very low potential."
69. M.F. Heady, *Rangeland Management* (McGraw Hill, New York, 1975).
70. B. Johnson, "Forestry Crisis—What Else Is New," *IUCN Bulletin*, Vol. 14, pp. 10–12 (October/December 1983).
71. World Resources Institute (WRI), *Tropical Forests: A Call for Action* Vols. I, II, and III (WRI, Washington, D.C., 1985), p. 1.
72. L.M. Talbot, "Strengthening the Role of the Private Sector in Addressing Tropical Forestry Issues" (World Resources Institute, paper, Washington, D.C., 1985), p. 7.
73. A. Grainger, "Increasing the Effectiveness of Afforestation Projects in the Tropics Involving Non-Governmental Organizations," *International Tree Crops Journal* Vol. 3, pp. 33–48 (1984).
74. J. Spears, "Forestry Research Needs in Developing Countries" (World Bank, paper, Washington, D.C., 1981).
75. K.R. Shea and L.A.W. Carlson, *Increasing Productivity of Multi-Purpose Tree Species: A Blueprint for Action* (U.S. Department of Agriculture, U.S. Forest Service, Washington, D.C., 1985).

# 6. Wildlife and Habitat

Wildlife resources include the earth's full complement of wild plants and animals, both individually as species and collectively as components of ecosystems. This year's discussion deals with maintaining diversity for both species and ecosystems. Subsequent editions of *World Resources* will treat such other topics as: wildlife management, commercial use of wild species, and the impacts and potential of new genetic technologies. Mammals, birds, fish, and plants dominate this chapter because they are the best known scientifically, and of most concern to people. Other vertebrates and invertebrates are discussed more briefly. Valuable micro-organisms are excluded here simply because few such species are known to be threatened.

Several million species of wildlife inhabit the earth. The overwhelming majority are invertebrates and plants. The numbers of species are most abundant in the tropics, and diminish toward the poles. However, gaps in data make it impossible to fully assess wildlife resources. In particular, most tropical species have scarcely been investigated, if even discovered.

This biotic wealth supplies most of our food, and much of the material we use for fuel, shelter, clothing, medicine, and other essential goods. It also provides recreation and enriches culture. Civilizations ultimately depend on the proper functioning of the ecosystems surrounding them.

Despite wildlife's importance, however, educated guesses of current species loss run to several thousand per year, and one million or more by century's end (1)—perhaps one quarter of the total now living. Human destruction of wildlife habitat causes most species loss. The destruction of tropical moist forests, where half of all species probably occur, poses a particularly serious problem.

## CONDITIONS AND TRENDS

Wise management of wildlife requires attention to both species and the living systems of which they are part. Although we examine the two states separately here, they are inextricably linked.

### SPECIES

When two distinguishable groups of organisms coexist without interbreeding, they are considered distinct species. However, scientists disagree on just how different two organisms must be in order to rank as species, rather than as subspecies or races. This disagreement underlies the variation in estimates of the numbers of existing species. It also influences how wildlife managers apply laws and practices.

Most species are rare; many are known from only one specimen. In an ecological zone with 100 species of birds, for instance, one dozen may be common and widespread, while the rest occur in small numbers. This phenomenon is particularly common in tropical forests, where individuals or pairs of many species are widely spaced. It makes such species more vulnerable to extinction and difficult to protect. Any low-density species requires expanses of suitable habitat to maintain healthy populations.

Of the many ways wild species serve human needs, a few stand out (2,3). Wildlife still directly provides a sizable fraction of the world's diet. A single taxon—shrimp—generates an annual retail trade worth more than $2.3 billion. Indirect uses are many. Wild forage feeds much of the world's domestic livestock. The productivity and resistance to pests and disease of domestic plants and animals rest heavily on the genetic resources of their wild or semi-domesticated relatives. About half of the world's medicinal compounds are still derived or obtained from plants (4). The value of such medicines has reached $20 billion per year in the United States, and double that amount in all the developed world. The centuries-old direct use of plants as medicine, which continues in many rural areas, represents a further unmeasured, but considerable value. Globally, trade in wood-based products now tops $100 billion annually (5), though in developing countries some three fourths of the wood harvested is burned as fuelwood, providing the principal source of energy for 2.5 billion people (6).

With the advent of genetic engineering, allowing the transfer of inherited characteristics from one species to another, the potential benefits of wild species expanded immensely. For instance, within a few years, genetic engineers hope to introduce the nitrogen-fixing capacity of a few plants into crops that now lack it. This will reduce the need for chemical nitrogen fertilizer and save the world's farmers an estimated $15 billion a year (7).

Numbers cannot describe the psychological, cultural, and spiritual values of wildlife, though money spent on wildlife-based recreation and tourism affords a hint. (See "Ecosystems," below.)

## How Many Species?

To date, about 1.7 million species have been identified. (See Table 6.1.) Of these, 4,200 are mammals, 8,700 are birds, 5,100 are reptiles, 3,100 are amphibians, and 21,000 are fish. Roughly 250,000 species of vascular plants have been described (8), as have 150,000 lower plants, such as mosses and lichens (9). Invertebrates account for all the rest—nearly 1.3 million species.

The actual number of species is certainly much higher, largely because the tropics are biologically so rich and so poorly known. A widely accepted minimum figure is 5 million (10,11,12,13). Many scientists believe the total could exceed 10 million. Based on rates of discovery, the ultimate total for mammals is expected to reach 4,300 species; birds, about 9,000; reptiles, 6,000; amphibians, 3,500; and fishes, 23,000. Thus, total vertebrates are expected to reach only 45,000 species—50,000, according to some zoologists. (See Table 6.1.) Around 30,000 undescribed vascular plants are thought likely to exist, most of them in the tropics (14). The greatest number of undescribed species are invertebrates and non-flowering plants.

**Table 6.1 Number of Species by Class**

| Class | Identified Species | Estimated Species |
|---|---|---|
| Mammals | 4,170 | 4,300 |
| Birds | 8,715 | 9,000 |
| Reptiles | 5,115 | 6,000 |
| Amphibians | 3,125 | 3,500 |
| Fishes | 21,000 | 23,000 |
| Invertebrates | 1,300,000 | 4,400,000[a] |
| Vascular Plants | 250,000 | 280,000 |
| Nonvascular Plants | 150,000 | 200,000 |
| Total[b] | 1,742,000 | 4,926,000 |

**Notes:**
a. This figure is a minimum. Recent research suggests there could be as many as 30 million insect species in tropical forests alone.
b. Totals are rounded.
**Sources:**
1. International Union for Conservation of Nature and Natural Resources (IUCN), Threatened Plants Unit, *Plants in Danger: What Do We Know* (IUCN, Conservation Monitoring Center, Cambridge, England, 1985).
2. P.H. Raven, *et al.*, 1981, Reference 8.
3. P.R. Ehrlich and A.H. Ehrlich, 1982, Reference 10.
4. E. Mayr, 1973, Reference 11.
5. N. Myers, 1979, Reference 1.
6. P.H. Raven, 1980, Reference 13.

So many invertebrates are being discovered that ultimate totals can only be guessed at. Indeed, in the late 1970s a Smithsonian Institution scientist studying caddis flies of the family Hydroptilidae collected in Amazonia found that of the 55 species represented, 53 were new (15). Another researcher suggests, on the basis of very limited findings, that the tropical forests alone could harbor 30 million insect species (16).

In reality, a close estimate of the earth's total number of species can never be attained because tropical forests, home to so many of them, are being converted to other uses at a rate of about 80,000 square kilometers per year, an area the size of Austria (17). At the same time, few scientists are qualified to describe new tropical species. Colombia, for example, has an estimated 40,000 plant species, but only a few dozen professional botanists. (In contrast, Great Britain has more botanists than its 1,445 plant species.) Worldwide, only 1,500 taxonomists and systematists study tropical organisms.

## Distribution and Diversity

The world's species are distributed irregularly. Some are widespread, occurring over most of a continent or, in some cases, several continents. The osprey, for example, lives on lakes, rivers, and coasts in most parts of the world outside the polar regions. Others are exceedingly local. For example, the tiny El Segundo Blue, a critically imperiled butterfly, is confined to two small plots in Los Angeles, California; one, limited to less than half a hectare, is surrounded by an oil refinery (18). The full distribution of most species, however, is unknown.

Some of the earth's zones are much richer in species than others. As far as can be judged, some two thirds of all species occur in the tropics, which occupy 42 percent of the earth's land surface. (See Table 6.2.) More important still, half of all species apparently occur in moist tropical forests, which cover only 7 percent of the earth's land surface (19). These forests now support at least 90,000 and perhaps as many as 120,000 species of vascular plants. By contrast, the entire northern temperate zone, including North America and Eurasia, has only 50,000 species of flowering plants. If the global total is only 5 million species, tropical forests in Latin America probably support 1 million species of plants and animals, South and Southeast Asia about three quarters of a million (most in Southeast Asia), and Africa about one third of a million (20).

In certain parts of the world, where geographic or ecological isolation has promoted speciation and made species immigration difficult, endemism is high—that is, a high proportion of species live only in these areas. Of Hawaii's more than 2,400 species and varieties of flowering plants, 97 percent are endemic (21). All but four of the more than 200 cichlid fishes found in Lake Malawi in southern Africa are endemic (22). Areas with a Mediterranean type of climate—parts of California, central Chile, southwestern and southern Australia, the Cape sector of South Africa, and the Mediterranean basin itself—are restricted ecological zones with high rates of endemism. Of the 25,000 species of flowering plants in these regions, about half are endemic (23). Past ecological isolation can also produce high endemism. Drier, cooler periods during the Pleistocene are thought by many scientists to have created "islands" of tropical moist forests in the Amazon and Africa as land around them became drier savannas. Today, these forest areas still exhibit high species endemism.

Within the biologically diverse tropics, certain areas stand out as unusually diverse. Within the 1.7 square kilometers of the Rio Palenque Research Station in western Ecuador, 1,025 plant species have been found—the highest plant diversity recorded anywhere (24). Other rich areas include Brazil's Atlantic coastal forest, Central America's Mosquitia Forest, Colombia's Choco Forest, parts of Amazonia, a small slice of Madagascar, the Tai Forest of the Ivory Coast, the montane forests of East Africa, the relict wet forest in Sri Lanka, the monsoon forests of the Himalayan foothills, northwestern Borneo, the Maldive Islands, certain Philippine lowlands, and several South Pacific islands, notably New Caledonia.

Many of these areas have a high degree of endemism as well as biological diversity. Thus, they are doubly important for species conservation. Yet, already some are largely destroyed as natural areas, and the others are rapidly being degraded.

**Table 6.2 Number of Species by Climatic Zones**

| Zone | Identified Species (millions) | Estimated Species (millions) Assuming 5 million total | Assuming 10 million total |
|---|---|---|---|
| Boreal | 0.1 | 0.1 | 0.1 |
| Temperate | 1.0 | 1.2 | 1.3 |
| Tropical | 0.6 | 3.7 | 8.6 |
| **World** | **1.7** | **5.0** | **10.0** |

**Sources:**
1. *International Union for Conservation of Nature and Natural Resources (IUCN), Threatened Plants Unit, Plants in Danger: What Do We Know* (IUCN, Conservation Monitoring Center, Cambridge, England, 1985).
2. P.H. Raven, *et al.*, 1981, Reference 8.
3. P.R. Ehrlich and A.H.Ehrlich, 1982, Reference 10.
4. E. Mayr, 1973, Reference 11.
5. N. Myers, 1979, Reference 1.
6. P.H. Raven, 1980, Reference 13.

Coral reefs also play host to unusually high numbers of species. For example, preliminary surveys of the Ningaloo Reef Tract, a fringing reef running for 260 kilometers along Australia's west coast, have recorded 170 species of corals, 90 echinoderms, about 600 mollusks, and 480 fish (25).

At the low end of the diversity spectrum are ice caps, tundra, and boreal forests. Canada, much of which is tundra or boreal forest, has only 22 species of snakes, while Mexico has 293 (26). As discussed below, regions of low diversity require a different conservation approach than do high-diversity zones.

## THREATENED SPECIES

Conservation and management of wildlife resources to date have focused largely on species with known economic value, such as timber and fruit trees, certain marine fish, and game species, especially mammals and birds. But a broader approach is now beginning to take hold—one in which *all* species are considered valuable, and attention is being directed toward those in known difficulty: "threatened species."

The International Union for Conservation of Nature and Natural Resources (IUCN) lists three major types of threatened species: those *endangered* because of near-term threats to the regenerating populations; those that are *vulnerable* over time because populations are declining in number or geographical distribution; and species that are *rare* because their total population is small or restricted in area. IUCN's Conservation Monitoring Center maintains data bases on globally threatened species and periodically publishes and updates the *Red Data Books* on major groups of plants and animals. These books highlight the world's most critically threatened species. Perhaps their most important benefit has been to stimulate local and national efforts to list threatened species and publish regional red data books.

### Temperate Zone

Some of the best data on temperate zone wildlife trends come from replies to questionnaires distributed by the Organization for Economic Cooperation and Development (OECD), and from the annual breeding bird survey conducted by the U.S. Fish and Wildlife Service. The OECD study shows that among declining mammals, large species (including grizzly and polar bears, wolves, wild cats, and the blue, humpback, and sperm whales), figure prominently. A few species, such as the white-tailed deer, beaver, coyote, raccoon, and some rats, are expanding in number or territory, largely as a result of habitat modification or translocation by people. In OECD countries, roughly one fourth of all mammals have been officially identified as threatened. In West Germany, the Netherlands, Austria, and Spain, more than 40 percent of all native mammalian species are threatened (27). (See Table 6.3.)

Birds appear to be slightly better off than mammals in terms of both population trends and percentages of species threatened. Species that require undisturbed habitat

**Table 6.3 Status of Species in Selected OECD Countries, Early 1980s**

| | Mammals | | | | | Birds | | | | | Reptiles | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Species Known | Threatened[a] | | Decreasing | | Species Known | Threatened[a] | | Decreasing | | Species Known | Threatened[a] | | Decreasing | |
| | | Number | % | Number | % | | Number | % | Number | % | | Number | % | Number | % |
| Canada | 94 | 6 | 6.4 | 5 | 5.3 | 434 | 10 | 2.3 | 8 | 1.8 | 32 | 2 | 6.3 | 5 | 15.6 |
| United States[b] | 466 | 35 | 7.5 | X | X | 1,090 | 69 | 6.3 | X | X | 368 | 25 | 6.8 | X | X |
| Japan | 186 | 4 | 2.2 | A | A | 632 | 35 | 5.5 | A | A | 85 | 3 | 3.5 | A | A |
| Australia | 320 | 43 | 13.4 | X | X | 700 | 23 | 3.3 | X | X | 550 | 9 | 1.6 | X | X |
| New Zealand | 68 | 14 | 20.6 | 21 | 30.9 | 282 | 16 | 5.7 | 46 | 16.3 | 37 | 7 | 18.9 | 7 | 18.9 |
| Austria[c] | 83 | 38 | 45.8 | X | X | 201 | 121 | 60.2 | 1 | X | X | X | X | X | X |
| Denmark | 49 | 14 | 28.6 | 16 | 32.7 | 190 | 41 | 21.6 | 68 | 35.8 | 5 | 0 | 0.0 | 4 | 80.0 |
| Finland | 62 | 21 | 33.9 | 11 | 17.7 | 232 | 15 | 6.5 | 24 | 10.3 | 5 | 1 | 20.0 | 1 | 20.0 |
| France[d] | 107 | 34 | 31.8 | 30 | 28.0 | 264 | 79 | 29.9 | X | X | 32 | 4 | 12.5 | X | X |
| Germany[c, e] | 94 | 44 | 46.8 | A | A | 455 | 98 | 21.5 | A | A | 12 | 9 | 75.0 | B | B |
| Italy | 97 | 13 | 13.4 | 35 | 36.1 | 419 | 60 | 14.3 | X | X | 46 | 24 | 52.2 | 25 | 54.3 |
| Netherlands[e] | 60 | 29 | 48.3 | 28 | 46.7 | 257 | 85 | 33.1 | 52 | 20.2 | 7 | 6 | 85.7 | 6 | 85.7 |
| Norway | 71 | 10 | 14.1 | 3 | 4.2 | 280 | 28 | 10.0 | 17 | 6.1 | 5 | 1 | 20.0 | 0 | 0.0 |
| Portugal | 79 | X | X | X | X | 337 | X | X | X | X | 24 | X | X | X | X |
| Spain[f] | 100 | 53 | 53.0 | 34 | 34.0 | 389 | 142 | 36.5 | 122 | 31.4 | 49 | 20 | 40.8 | 13 | 26.5 |
| Sweden | 63 | 11 | 17.5 | X | X | 250 | 34 | 13.6 | X | X | 6 | 0 | 0.0 | X | X |
| Switzerland | 86 | X | X | X | X | 190 | 74 | 38.9 | X | X | 15 | X | X | X | X |
| Turkey | 31 | 11 | 35.5 | 11 | 35.5 | 217 | 36 | 16.6 | 81 | 37.3 | X | X | X | X | X |
| United Kingdom[g] | 51 | 12 | 23.5 | X | X | 200 | 24 | 12.0 | X | X | 6 | 2 | 33.3 | X | X |

Capital letters in the table refer to estimates of the number of species in each category:
A = several species B = many species X = not available

**Notes:**
a. Threatened refers to the sum of the number of species in the endangered and vulnerable categories.
b. Including Pacific and Caribbean Islands.
c. Data for threatened animals include extinct and/or vanished species.
d. Data for known freshwater fish species only.
e. The number of bird species known includes occasional visitors.
f. Peninsular Spain and the Baleares only.
g. Data refer only to terrestrial mammals.

**Source:** Organization for Economic Cooperation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985).

and nesting sites or somewhat rare foods—the black woodpecker (*Dryocopus martinus*) in Norway, for instance—have declined, while pigeons, gulls, egrets, sparrows, and other birds that adapt well to the presence of people have increased and spread. Austria, Switzerland, Spain, and the Netherlands have the largest percentages of threatened birds—between 33 and 60 percent. An annual survey of breeding birds conducted by the U.S. Fish and Wildlife Service in the continental United States and Canada shows significant increases in population for 64 species (16 percent) and significant declines for 48 (12 percent) between 1968 and 1979 (28). Two major factors influenced these results. One was bird die-offs in the late 1960s due to the use of long-lasting pesticides such as DDT. Another was massive outbreaks of the spruce budworm, which boosted food supplies in northern forests during the 1970s.

Reptiles and amphibians appear to be even harder pressed than mammals and birds in OECD countries, especially European countries. Denmark, for instance, reported that four of its five reptile species and *all* of its 14 amphibians are decreasing. West Germany, Italy, the Netherlands, and Spain all reported over 40 percent of their reptile and amphibian species as threatened.

Among vertebrates, fishes (including many non-commercial marine species) appear the least threatened in OECD countries. Many countries, however, are adding more fish to their official lists as better information is obtained. Most decreases in fish populations are attributed to the loss of breeding and nursery grounds because so many wetlands, bays, estuaries, and coastal marshes have been filled or polluted. Overfishing has decimated some important commercial species, such as Atlantic herring and haddock.

A few countries reported small numbers of threatened invertebrates. (More data would probably put many more species in this category.) Nine countries submitted information on numbers of threatened plants—which ranged from near zero to West Germany's 29 percent. This suggests that the OECD countries approximate the world average for endangered plants (10 percent) roughly estimated by IUCN (29).

## Tropical Zone

Data on population trends for tropical species are few, but many tropical forest species are undoubtedly declining, simply because their habitats are rapidly being cleared, and few tropical species can survive anywhere else. Of 401 bird species and sub-species listed as threatened in the *Red Data Books*, 291 live in tropical moist forests (30). Of key concern are the forest areas where species diversity and endemism are unusually high.

Farming, grazing, fires, firewood cutting, and desertification are altering tropical savannas and grasslands too. Along with hunting, these changes are reducing the number of larger animal species, especially mammals, and probably many smaller ones. In general, however, savanna species seem better able to survive on farms and other altered habitats than tropical forest species. Some, like the black-faced dioch (a grain-eating bird) and various species of locusts, thrive and become serious pests.

Information on threatened species by country is available for Latin America. "Diversity profiles" have been generated from the U.S. Nature Conservancy's computerized data base on the status of habitat conservation, major ecosystems, and terrestrial vertebrate species throughout the neotropical region (31). (See Table 6.4.) For

| Amphibians | | | | | Fishes | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species Known | Threatened[a] | | Decreasing | | Species Known | Threatened[a] | | Decreasing | |
| | Number | % | Number | % | | Number | % | Number | % |
| 54 | 2 | 3.7 | 2 | 3.7 | 800 | 15 | 1.9 | X | X |
| 222 | 8 | 3.6 | X | X | 2,640 | 44 | 1.7 | X | X |
| 58 | 1 | 1.7 | A | A | 3,144 | 4 | 0.1 | A | A |
| 150 | 6 | 4.0 | X | X | 3,200 | X | X | X | X |
| 6 | X | X | 2 | 33.3 | 777 | 3 | 0.4 | 77 | 9.9 |
| X | X | X | X | X | 92 | 54 | 58.7 | X | X |
| 14 | 3 | 21.4 | 14 | 100.0 | 166 | 17 | 10.2 | 20 | 12.0 |
| 6 | 0 | 0.0 | 1 | 16.7 | 58 | 4 | 6.9 | 10 | 17.2 |
| 30 | 6 | 20.0 | X | X | 70 | 13 | 18.6 | X | X |
| 19 | 11 | 57.9 | B | B | 173 | 40 | 23.1 | A | A |
| 28 | 13 | 46.4 | 26 | 92.9 | 503 | 70 | 13.9 | 112 | 22.3 |
| 15 | 10 | 66.7 | 8 | 53.3 | 49 | 11 | 22.4 | A | A |
| 5 | 1 | 20.0 | 3 | 60.0 | X | X | X | X | X |
| 17 | X | X | X | X | X | X | X | X | X |
| 23 | 18 | 78.3 | 4 | 17.4 | 137 | 12 | 8.8 | 5 | 3.6 |
| 11 | 5 | 45.5 | X | X | X | X | X | X | X |
| 20 | X | X | X | X | 60 | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| 6 | 2 | 33.3 | X | X | 37 | 8 | 21.6 | X | X |

the region, 11 percent of the 3,812 bird species, 11 percent of the 1,234 mammals, 5 percent of the 2,420 reptiles, and less than 1 percent of the 1,833 amphibians have been listed as threatened. By country, the percentage of vertebrate species threatened ranges from 8 percent for Mexico to 15 percent for Paraguay and Uruguay. Compared to the OECD countries, Latin America and the Caribbean appear to be much healthier with respect to species populations, probably in part because human density is lower in the neotropics. (Better information from the OECD countries could also account for some of the difference.) Human pressure is increasing, however, especially on tropical forests.

Similar data are not yet available for tropical Asia. For Africa, numbers of globally threatened mammal species have been determined on a country-by-country basis. (See Part IV, "Wildlife Resources," Table 7.3.) The number of species threatened ranges from zero in São Tome to 17 in Zaire and 18 in Nigeria.

Scientists express greatest concern for threatened African plants in South Africa and Madagascar. Plant diversity, endemism, and the degree of threat are high in both countries, though data are more complete for South Africa. The Cape Floristic Kingdom in southwestern South Africa, one of the world's botanically richest and most distinctive areas, harbors 6,000 plant species, 70 percent of them endemic. Mainly because of agricultural activity, fires, and invasion of exotic plants, at least 2,000 are threatened (33).

### Wetlands and Oceans

Many wetland species are declining because of habitat reduction and degradation. In the United States, for example, 40 percent of the wetland areas have been drained or filled since 1850, endangering approximately half of all U.S. freshwater mollusk species (34). In Great Britain, almost all amphibians—even the common frog—are threatened.

In the oceans, hunted species of whales have declined. Even with harvesting quotas for some species and whaling bans on others, whale stocks are not recovering (35). The California gray whale is the one exception. (See Figure 6.1.) Coral reef species are declining too as a result of coral removal and dynamite fishing.

## VULNERABLE GROUPS

Certain inherent characteristics make some species more vulnerable than others. The populations of many threatened species have always been small and local, either because they evolved in unique geographic situations or because they required certain rare foods or habitats. For instance, the Kirtland's warbler (*Dendroica kirtlandii*) is now reduced to about 400 individuals in the United States in northern Michigan. This warbler can breed only in thickets of young jack pines that spring up after fires—a habitat found in only a few states and Canadian provinces. Such isolated and inbred populations are especially vulnerable to severe weather, epidemics, or other catastrophic events.

Island species are also unusually vulnerable. Many have evolved on islands with few if any predators or herbivores. As a result, they lack such normal defense mechanisms as flight in birds, or poisonous chemicals and spines in plants. When people introduce predators or herbivores to islands, many native species are wiped out. The flightless dodo on Mauritius is a familiar example. On St. Helena, which was settled by Europeans in the 16th Century and overrun with their goats, 22 of 33 endemic plant species have disappeared since 1810 (36).

Animal species that either forage or breed in large aggregrations are also susceptible to decimation. Some, including certain whales and dolphins, expose themselves to danger by coming to the aid of dead or wounded members of the group. Those that require large breeding colonies may, like the passenger pigeon (*Ectopistes migratorius*), fail when their populations fall below a certain size due to hunting or other causes.

Slow reproducers, often large mammals or birds, represent another vulnerable group of species. These species can maintain their populations in natural situations because their young enjoy high survival rates. But their recovery from catastrophe or human exploitation is very slow. The California condor—now down to fewer than 10 individuals in the wild—does not breed until at least six years of age, lays only one egg, and fails to nest at all in some years. A pair of condors thus requires 10–15 years to replace itself (37).

Finally, some species require large areas to maintain themselves, or for other reasons occur at very widely spaced intervals. Large carnivores need expansive hunting territories to find enough prey, and hornbills need great amounts of space in which to find food. In several African parks, lions require anything from one to 40 square

**Table 6.4 Status of Resident Terrestrial Vertebrates in Latin America, 1985**

| Region or Country | Mammals | | Birds | | Reptiles | | Amphibians | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Number | % Threatened or Endangered[a] | Total Number | % Threatened or Endangered[a] | Total Number | % Threatened or Endangered[a] | Total Number | % Threatened or Endangered[a] | Total Number | % Threatened or Endangered[a] |
| Latin America and the Caribbean | 1,234 | 11 | 3,812 | 11 | 2,420 | 5 | 1,833 | 1 | 9,299 | 7 |
| Mesoamerica Region (Mexico and C. America) | 559 | 8 | 1,318 | 12 | 930 | 4 | 505 | 1 | 3,312 | 7 |
| Tropical Andean Region | 602 | 14 | 2,518 | 10 | 823 | 6 | 818 | 0 | 4,761 | 8 |
| Guiana Region | 330 | 12 | 1,354 | 11 | 286 | 10 | 229 | 0 | 2,199 | 10 |
| Tropical Atlantic Region | 419 | 19 | 1,598 | 13 | 475 | 8 | 491 | 0 | 2,983 | 11 |
| Southern Cone Region | 284 | 17 | 1,007 | 12 | 266 | 8 | 156 | 0 | 1,713 | 11 |
| Caribbean Islands Region | 141 | 13 | 639 | 16 | 434 | 12 | 138 | 1 | 1,352 | 13 |
| Mexico | 439 | 7 | 958 | 13 | 702 | 5 | 273 | 1 | 2,372 | 8 |
| Guatemala | 174 | 12 | 666 | 14 | 201 | 8 | 98 | 0 | 1,139 | 12 |
| Belize | 121 | 15 | 505 | 13 | 109 | 10 | 24 | 0 | 759 | 13 |
| Honduras | 179 | 13 | 670 | 13 | 154 | 8 | 53 | 0 | 1,056 | 12 |
| El Salvador | 129 | 12 | 431 | 15 | 86 | 12 | 36 | 0 | 682 | 13 |
| Nicaragua | 177 | 14 | 609 | 13 | 165 | 10 | 58 | 0 | 1,009 | 12 |
| Costa Rica | 203 | 13 | 795 | 12 | 220 | 8 | 151 | 1 | 1,369 | 10 |
| Panama | 217 | 14 | 840 | 12 | 207 | 9 | 155 | 1 | 1,419 | 10 |
| Colombia | 358 | 17 | 1,665 | 11 | 371 | 9 | 362 | 1 | 2,756 | 10 |
| Venezuela | 305 | 12 | 1,295 | 11 | 244 | 10 | 176 | 0 | 2,020 | 10 |
| Guyana | 198 | 14 | 732 | 13 | 136 | 14 | 106 | 0 | 1,172 | 12 |
| Suriname | 200 | 16 | 674 | 13 | 130 | 14 | 99 | 0 | 1,103 | 13 |
| French Guiana | 142 | 20 | 627 | 13 | 135 | 16 | 90 | 0 | 994 | 13 |
| Brazil | 394 | 20 | 1,561 | 13 | 462 | 8 | 479 | 0 | 2,896 | 11 |
| Ecuador | 280 | 18 | 1,449 | 11 | 344 | 8 | 349 | 0 | 2,422 | 10 |
| Peru | 359 | 17 | 1,640 | 10 | 291 | 8 | 233 | 0 | 2,523 | 10 |
| Bolivia | 267 | 19 | 1,179 | 12 | 174 | 10 | 96 | 0 | 1,716 | 12 |
| Chile | 90 | 20 | 393 | 10 | 80 | 5 | 40 | 0 | 603 | 10 |
| Argentina | 255 | 16 | 927 | 13 | 204 | 8 | 124 | 0 | 1,510 | 12 |
| Paraguay | 157 | 21 | 629 | 16 | 111 | 11 | 751 | 0 | 966 | 15 |
| Uruguay | 77 | 29 | 368 | 13 | 65 | 15 | 35 | 0 | 545 | 15 |
| Cuba | 39 | 23 | 286 | 13 | 98 | 16 | 39 | 0 | 462 | 13 |
| Hispaniola | 23 | 17 | 212 | 12 | 133 | 8 | 53 | 0 | 391 | 10 |
| Puerto Rico | 17 | 12 | 221 | 13 | 46 | 20 | 25 | 4 | 309 | 13 |
| Jamaica | 29 | 10 | 223 | 10 | 38 | 18 | 20 | 0 | 310 | 10 |
| Bahamas | 17 | 18 | 219 | 8 | 39 | 31 | 2 | 0 | 277 | 12 |
| Lesser Antilles | 37 | 11 | 193 | 14 | 91 | 13 | 15 | 0 | 336 | 13 |
| Tobago | 29 | 10 | 160 | 11 | 39 | 26 | 8 | 0 | 236 | 13 |
| Trinidad | 85 | 7 | 347 | 15 | 74 | 19 | 14 | 0 | 520 | 14 |
| Netherlands Antilles | 9 | 22 | 171 | 10 | 22 | 18 | 2 | 0 | 204 | 11 |

**Note:**
a. Listed on CITES Appendices I, II, and III; on U.S. Department of Interior, Fish and Wildlife Service, threatened and endangered species list; or in the International Union for Conservation of Nature and Natural Resources (IUCN) *Red Data Books*.
**Source:** The Nature Conservancy International Program (TNCIP), The Latin American/Caribbean Regional Conservation Data Center (TNCIP, Typescript, Washington, D.C., 1985).

kilometers each. Grizzly bears in Yellowstone National Park in the United States have, on average, 50 square kilometers each (38). Many tropical trees are widely spaced too, though each individual uses the resources of a relatively small area. Without large areas of suitable habitat, such species will dwindle or even die off.

## Causes of Depletion

Besides the enormous losses resulting from habitat destruction, direct, targeted depletion threatens many species. A common form is overhunting for meat, furs, and other products. Among obvious examples are the great whales, seals, the California sardine, wild cats (such as the tiger, clouded leopard, and cheetah), and the now-extinct great auk.

Probably the most salient recent instance of direct depletion is the African rhino. In 1980, the black rhino population stood at 15,000, but by 1985 fewer than half that number remained. (In the Central African Republic, numbers plunged from 3,000 to about 150.) As for the white rhino, the southern race has increased slightly, but the northern race has dropped from almost 1,000 to at most one dozen (39). The three species of Asian rhinos, though somewhat better protected, are equally threatened, with numbers of the rarest—the Javan rhinoceros—down to about 50.

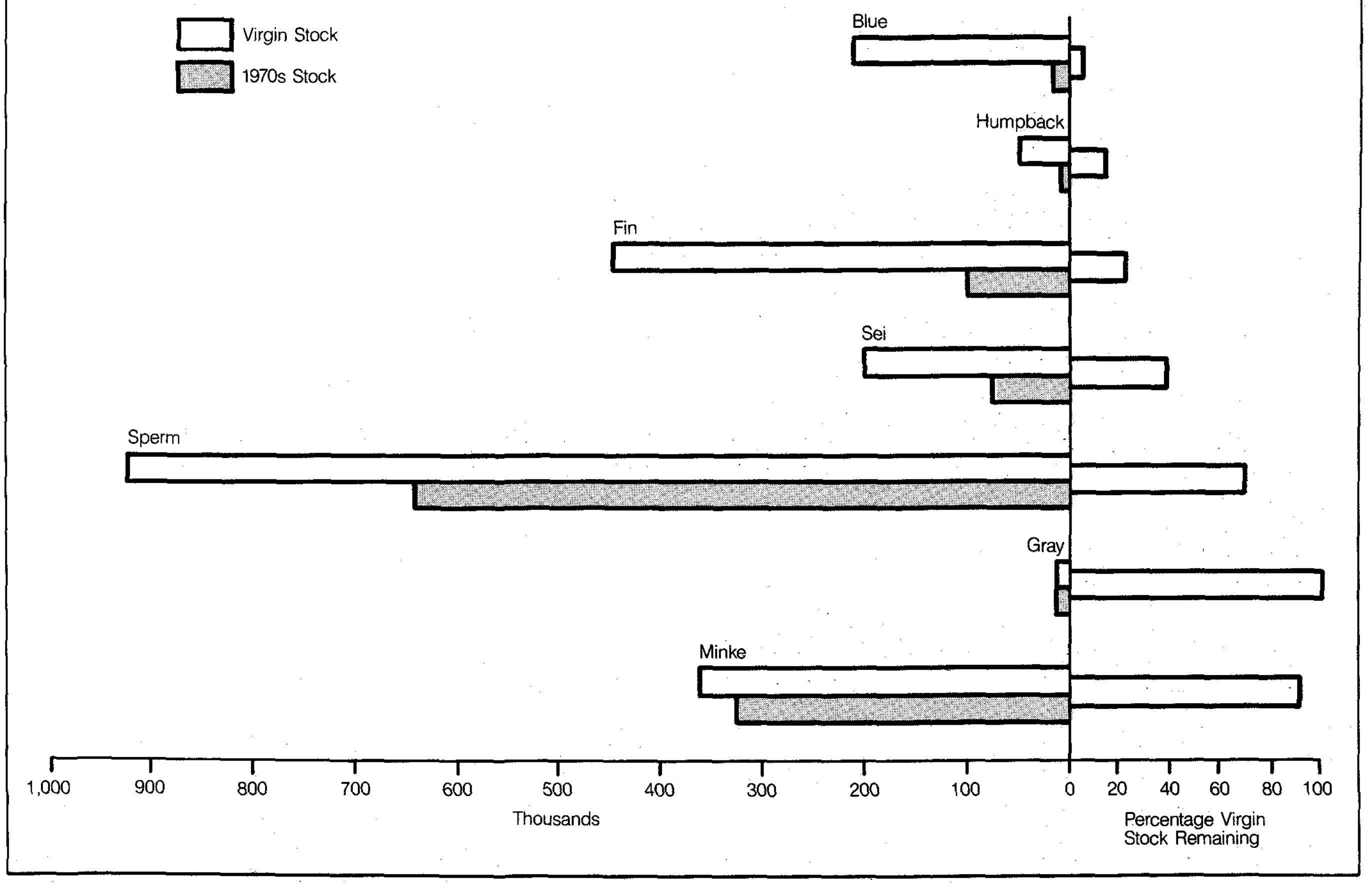
African elephants are overhunted for their ivory. Ivory exports of about 1,000 tons per year represent 90,000 or more dead elephants—almost twice the 5 percent annual cropping that the estimated one million or so elephants left in Africa can sustain. Although the number of elephants surviving in Africa, especially in the vast forests of the Zaire Basin, is uncertain, a 10 percent annual kill could halve remaining populations within a decade.

Trade in live plants and animals has taken its toll on many species. Among plants, orchids and cacti are prime targets. In 1977, U.S. legal imports of succulents, mostly cacti, from Mexico totaled 7 million plants. Illegal, hence unrecorded, imports are also substantial. U.S. imports of one Mexican cycad were believed to have wiped out the entire wild stock of the species (40). In 1983, 29 golden-headed lion tamarins, a severely threatened primate from coastal Brazil, were imported into Belgium (41). Scientists believe that fewer than 1,000 of these animals remain in the world.

## Extinction

Species extinction has occurred since life's emergence on Earth almost 4 billion years ago. Of the estimated half billion species that have ever existed, modern survivors today probably number 5 to 10 million species. But

**Figure 6.1 Whale Exploitation, by Species, Pre-hunting through the 1970s**




**Sources:**
1. V.B. Scheffer, "The Status of Whales," *Pacific Discovery*, Vol. 29, No. 1, p. 3 (1976).
2. W.E. Scherill, Ed., *The Whale Problem: A Status Report* (Harvard University Press, Cambridge, Massachusetts, 1974), pp. 306–307.
3. Committee for Whaling Statistics (CWS), *International Whaling Statistics* (CWS, Sandefjord, Norway, 1979), p. 12 and p. 17.

almost all past extinctions have occurred naturally. Only in the past 50,000 years or so have people exerted much influence as hunters, food-gatherers, and cultivators. And only in the past four centuries has advancing technology made possible massive human-caused losses of habitat and species.

Predictions of species losses by the end of this century, based on recent land-use trends, rise to a million or more. Some scientists believe that almost 20 percent of all species live in Latin American forests outside of Amazonia and that another 20 percent live in the forests of Asia and Africa outside the Zaire Basin. *All* of these forests may well disappear within the next 25 years or so. If only half of the species they contain disappear, at least three quarters of a million of Earth's estimated 5 million species will die (42). In the next century, if present rates of forest loss continue, one third or more of all species could be lost—a mass die-off that would rival past extinctions that occurred over millions of years (43).

## PROTECTION OF THREATENED SPECIES

Methods to protect threatened species include legislation, habitat protection, wildlife management, and maintenance of individuals in zoos, botanical gardens, and other artificial habitats.

The starting point for protection of species has always been laws, regulations, and policies. Most early laws dealt with game animals, fish, and migratory birds. More recent legislation also protects reptiles, amphibians, invertebrates, and plants. A far-reaching example of a law directed solely at threatened species is the 1973 U.S. Endangered Species Act. This legislation was enacted to protect the species officially listed as endangered and their "critical habitat." The law also initiated recovery programs. To date, about 370 species or subspecies have been listed as endangered or threatened under the law, and some 185 recovery plans for species or groups of species have been approved (44). Most countries outside the OECD also have laws protecting at least some species, but enforcement varies greatly from country to country.

Several international treaties and conventions now protect wildlife species, but most are bilateral or regional. Among the most far-reaching is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), administered by the United Nations

Environment Program (UNEP). Since CITES came into force in 1975, 87 countries have become parties, and more than 700 species have been listed (45). Although nearly all the main producer and consumer nations are parties to the Convention, notable exceptions include New Zealand (which implements many CITES provisions) and Singapore (which is a major center for distributing wildlife and wildlife products). Certainly more nations need to accede to the treaty. Other weaknesses of this protection system include failures to report trade statistics to central information clearinghouses and the lack of implementing legislation in some countries.

By far the most effective way to protect species is to provide ample secure habitat. Most of the thousands of protected areas around the world were not established primarily to benefit one or a few species. Many, however, do harbor threatened species. Geneticists believe that 50–250 individuals of most mammalian species are needed in such areas for healthy breeding (46). Given the possibility of local catastrophes and other dangers, many wildlife scientists put that figure at several hundred or several thousand individuals for a plant or animal species. As for space needs, a viable population of a species of butterfly might be sustained within a few square kilometers, whereas grizzly bears may require more than 20,000 square kilometers.

Among the protected areas established primarily for one species are such diverse sites as the tiny Addo Elephant National Park in South Africa and ten reserves established in China for the giant panda. Under Project Tiger in India, a dozen or so new reserves were created and others expanded, in part to broaden the range of ecosystems under protection. As a result, India's tiger population rose from about 1,800 in 1972 to around 4,000 today; swamp deer, Asian elephants, rhinos, wild water buffalos, and other rare species benefited as well.

Close management of a threatened species in the wild can succeed when its population dynamics are well understood and its economic or other value has been recognized. An outstanding example is the vicuna recovery in the Andes. In Peru and other countries, the vicuna declined because of overhunting for its valuable fur. Only 7,500 animals survived in the late 1960s (47). New controls on cropping, hunting, and pasture use have pushed the population to almost 100,000 today.

Efforts to protect species by sequestering individuals in zoos, botanical gardens, and seed banks are a last resort. Zoos and botanical gardens have room for relatively few species and individuals, and maintenance costs are high. But captive breeding and the reintroduction of eggs or young to the wild has sometimes proven effective, as with the peregrine falcon and some crane species. In gene banks, the seeds of many plant species (especially those with dry, small seeds) can be stored dormant for long periods. The Fort Collins facility of the U.S. Department of Agriculture contains 100,000 samples of more than 1,300 plant species, with a capacity for at least 500,000 samples. But this technique does not work with most vegetatively propagated plants (such as orchids) and many other tropical species. Also, refrigerated storage in effect freezes evolution, possibly rendering stored material less fit to meet changes that meanwhile occur in its natural environment.

However costly and time-consuming, the species approach to wildlife conservation is sometimes necessary. In practice, though, more of the larger spectacular species (especially mammals) get saved. Protecting such species does win public support. And while it automatically provides sanctuary for many smaller forms, it is usually less effective than conserving wildlife resources by preserving whole ecosystems.

## ECOSYSTEMS

The survival of wildlife populations depends primarily on the extent and condition of their habitats. Thus an assessment of the world's great range of ecosystems—communities of species and their physical environment—is essential. (See Figure 6.2.)

All of the earth's environments have been altered by human activity, some drastically. How well wild species adapt to such alterations largely determines their future. Few species can tolerate much environmental disturbance, so their survival depends on preventing or managing disturbance in protected areas.

Ecosystems have values besides those of the wildlife. Expenditures in the United States for non-consumptive recreation associated with wildlife and its habitat were estimated at $14.8 billion in 1980. U.S. expenditures by hunters and fishermen on fees, transportation, equipment, food, and lodging rose from $5.7 billion in 1960 to $16 billion in 1980 (in constant 1975 dollars) (48). The value of tourism and recreation in other countries is not nearly so large, but can constitute a greater share of national economies. In Kenya, for example, safari-centered tourism is the second most important source of foreign exchange after coffee.

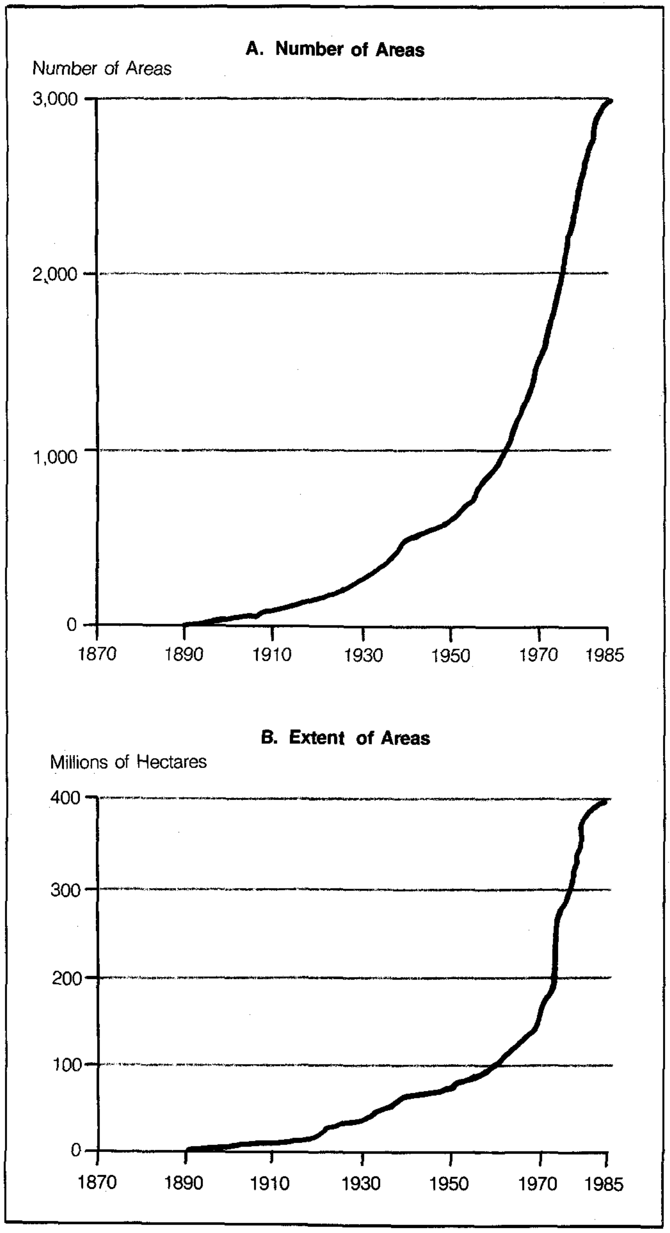
Ecosystems also supply environmental services. They maintain the quality of the atmosphere by balancing amounts of nitrogen, oxygen, and other critical gases. They control and ameliorate climate and weather by profoundly influencing the global patterns of air circulation. They regulate freshwater supplies, dispose of wastes, recycle nutrients, and generate, maintain, and protect soils. Often, these "free" environmental services are not appreciated until an ecosystem is disrupted—until, for instance, a watershed is deforested and downstream areas flood or fill with sediment.

### Extent and Condition of Ecosystems

Global estimates of the size of major ecosystems and changes in their extent are sketchy, though improving with the quality of satellite imagery. A study of global land use showed that cultivation now occupies 17.46 million square kilometers (13 percent) of the earth's surface (49). (See Table 6.5 and Part IV, "Land Use and Cover," Table 4.2 for details.) Most of this was once grassland, forest, or woodland.

In terms of total area lost, the greatest reduction since pre-agricultural time has occurred in forests, especially temperate forests. While such forests have slightly

**Figure 6.2 Growth of the Global Network of Protected Areas, 1890–1985**




**Source:** International Union for Conservation of Nature and Natural Resources (IUCN), 1985, Reference 62.

increased in extent recently, their wildlife has not necessarily increased proportionately. Much of the expansion is in monocultural forest plantations, which support comparatively few species. Mature forests, with their greater biological diversity, have decreased, and younger stands now predominate. Acid precipitation has devastated some forests in Europe and has begun to affect others in North America. Forest fragmentation in much of the temperate zone renders many forest patches too small to support some species. Losses of tropical rain forests have accelerated over the past three decades. Thus, though this land use study—whose sources date largely from the beginning of this period—shows only a 4 percent loss in their original extent, estimates based on more recent data show losses of 25–40 percent (50).

Estimates of the current rate of conversion of tropical moist forest to other uses are uniformly high. A conservative estimate is that 12 percent of the 1980 extent of these forests will be lost by the year 2000 (51). Thailand may lose 60 percent; Guinea, 33 percent; Nigeria and the Ivory Coast, 100 percent; Costa Rica, 80 percent; and Honduras, Nicaragua, and Ecuador, at least 50 percent. (See Chapter 5, "Forests and Rangelands.")

The principal agent in the conversion of tropical forests is the slash-and-burn cultivator. The problem lies not so much with traditional shifting cultivators as with the *shifted* cultivators who find themselves landless in established farmlands. They head for the last unoccupied, "free" land available—the forests. In many countries, including the Philippines, Indonesia, Thailand, Madagascar, Ivory Coast, Kenya, and Guatemala, the numbers of slash-and-burn farmers are increasing by 4–7 percent each year. Worldwide, they now number at least 250 million, and the pressures they exert on land are expected to grow (52).

Countries such as Brazil, Indonesia, and Malaysia design large agricultural schemes to provide plots for the landless. These schemes require big chunks of forest. In Latin America, cattle ranching for the export trade plays a major role. Government figures attribute 38 percent of all deforestation in the Brazilian Amazon between 1966 and 1975 to large-scale cattle ranches, 31 percent to other agriculture, and 27 percent to highway construction (53).

Logging affects large areas because tropical tree species grow in low densities, and relatively few have commercial markets. Selective logging alone seldom destroys a forest, but the subsequent invasion of farmers along logging roads often does. Hydroelectric dams, mines, and other development projects also contribute to deforestation.

In total, conversion plus various degrees of degradation now probably affect about 200,000 square kilometers of moist tropical forest per year (54). How the alteration of tropical forests affects wildlife is poorly documented. Many experts concur that rending the fabric of a rain forest will unravel the whole system. Surveys of selectively logged forests in Southeast Asia suggest, however, that most primate and bird fauna, at least, return within 30–50 years if mature forest is available nearby as a refuge and source of recolonization (55).

**Table 6.5 Land Use and Cover, Pre-Agriculture to the Present**

| | (million square kilometers) | | | |
|---|---|---|---|---|
| Vegetation Type | Preagricultural Area | Present Area | Absolute Amount Lost | Relative Loss (percent) |
| All Forests | 49.86 | 42.10 | 7.76 | 16 |
| Tropical rainforests | 12.80 | 12.30 | 0.50 | 4 |
| Other forests | 37.06 | 29.80 | 7.26 | 20 |
| Woodland | 12.32 | 10.44 | 1.88 | 15 |
| Shrubland | 13.12 | 12.15 | 0.97 | 7 |
| Tundra | 7.35 | 7.35 | 0.00 | 0 |
| Grassland | 34.01 | 27.45 | 6.56 | 19 |
| Desert | 15.85 | 15.58 | 0.27 | 2 |
| Cultivation | 0.00 | 17.46 | NA | NA |
| **Total** | **132.51** | **132.51** | **17.46** | **13** |

NA = not applicable
**Source:** E. Matthews, 1983, Reference 49.

Losses of the earth's original grasslands amount to 19 percent, though in the OECD countries total grassland area did not change from 1955 to 1983 (56). Most grasslands are subject to livestock grazing, which can reduce the number of palatable species of grass. This creates niches for invasive exotic weeds. In Australia, grazing contributed to the decline of many marsupials (57). In Africa and elsewhere, annual burning reduces the abundance of woody species and alters the composition of grass species, thus depriving some wild animal populations of food and cover. Hunting and livestock grazing have held the numbers of wild animals on grasslands far below their potential. Dryland agriculture is another common cause of grassland loss. It can lead to a long-term loss of habitat and of agricultural and range productivity.

While woodland losses amount to only about one-third that of forests or grasslands, the area represents almost 14 percent of the original extent of this ecosystem. The largest area affected is the dry African miombo, a fairly dense, short woodland where subsistence farming is widely practiced. In many areas, fire, grazing, hunting, and firewood-cutting have impoverished the wildlife resources of remaining woodlands.

Shrublands, generally too arid, cold, or mountainous for agriculture, have decreased by only 6.7 percent since pre-agricultural times. Fire, grazing, woodcutting, hunting, and drought have turned many shrublands and grasslands into near-deserts, thus transforming wildlife habitat. Shrubland is important for its hydrologic regulation in steep areas, as well as for wildlife habitat.

Though some confusion exists over how to define and measure desert, desertlike conditions appear to be spreading worldwide. Off-road vehicle use in arid lands has damaged plant communities considerably, especially in such settled deserts as those of southwestern United States. In the Sahara, shooting by the military and commercial hunting have nearly wiped out the scimitar-horned oryx, dama gazelle, and ostrich, while populations of other animals are dwindling (58). In contrast, other desert species are expanding as shrublands and grasslands desertify.

The area of tundra has not changed. The principal human impact on this environment has come through reindeer herding in northern Eurasia, oil and mineral exploration and production, and hunting and trapping—activities that have depleted populations of the barren-ground caribou and musk-oxen. Trampling and machinery use have also damaged tundra soils and vegetation, which are slow to recover.

Antarctica and other ice-covered regions have virtually no vegetation, but do have some wildlife. Seals, polar bears, and birds (including penguins) all ultimately depend on the sea for food. Hunting, and perhaps krill harvesting, have taken a toll on these resources, but currently they are relatively stable.

Although wetlands—home to economically important groups such as fish and waterfowl—are difficult to measure on a global scale, the area of marshes, ponds, swamps, and bogs has been shrinking rapidly. In the United States, 40 percent of all wetlands has been drained or filled since 1850 (59). In Japan, 33 percent of the tidelands, where shellfish and birds feed, were lost between 1945 and 1978 (60). The Pantanal in Brazil, at 110,00 square kilometers probably the world's most extensive wetland, is being encroached upon by agriculture.

In many parts of the world, both wetlands and lakes are subject to acid deposition and pollution from other sources. Lakes in parts of Europe, Canada, and the United States are especially threatened. One species of Canadian trout has been brought close to extinction as more and more Canadian lakes acidify (61).

## FOCUS ON: PROTECTED AREAS

The most effective defense against loss of wildlife is to establish and maintain protected areas. Conservationists, therefore, are working to create a worldwide system of protected areas as habitats for viable populations of most existing species—a permanent genetic pool of the earth's natural variety.

Besides national parks, many types of protected areas have evolved in recent decades. They range from scientific reserves to multiple-use areas where some exploitation, such as logging or hunting, is permitted. As human material needs grow, alternatives to the national park concept are being sought to better serve the many poor people who cannot afford to forego the consumption of natural resources for the sake of recreation and aesthetic enjoyment.

More than 3,500 major protected areas, totaling 4.25 million square kilometers, are included in IUCN's *1985 United Nations List of National Parks and Protected Areas* (62). The growth rates in the extent and number of protected areas rose particularly rapidly after 1950, especially in the non-OECD countries where the concept was comparatively new. (See Figure 6.3.)

Most protected areas on the U.N. list are between 1,000 and 100,000 hectares in size. A few dozen total over 1 million hectares each, including Greenland National Park, by far the largest at 70 million hectares. The average size of reserves is greatest in the Afrotropical and Nearctic Realms, where human settlement is sparse.

By country, the percentage of total area in protected status varies widely. Only about a dozen countries over 20,000 square kilometers in size have over 10 percent of their land in protected areas. These tend to be in Africa. Most countries fall below 5 percent, and a few have no protected areas at all. (See Table 6.6.) Quality of management and degree of protection also vary widely.

Existing protected areas have been classified by IUCN according to current management practice rather than title or management intent. (See Part IV, "Wildlife Resources," Technical Notes.) This ten-category framework permits international comparisons. The first five categories, the most significant for wildlife conservation, are used in the analysis below. At the Conservation Monitoring Center in Cambridge, England, IUCN maintains a data base providing information on location, size, management, and biological resources for national parks, wildlife reserves, national monuments, biosphere reserves, and other types of areas. Information on smaller conservation areas, such as private reserves or state parks, is also being accumulated.

## Biogeographical Zones

IUCN also classifies and maps biogeographical zones. Its system for assessing terrestrial environments, known as the Udvârdy classification (63), divides the world's land areas into eight major *realms* that are subdivided into 207 *provinces*. Each province, in turn, is characterized by one of 14 major *biome* types. For example, California's Sequoia National Park lies within the Nearctic Realm and the Sierra-Cascade Province, which is characterized as a Mixed Mountain and Highland System Biome. A second classification divides marine and coastal environments into *Ocean Realms*, *Coastal Realms*, and *Marginal Seas and Archipelagoes*, with 40 resulting *Faunal Provinces* along the coastlines (64). However, detailed classification of marine and coastal protected areas has not yet been completed.

Though useful, the biogeographical zone classification scheme can mislead (65). For example, the Palearctic Realm includes 122 protected areas covering 84,634 square kilometers in the Temperate Needle-Leaf Forests/Woodlands Biome, but only 9 areas covering 521 square kilometers in the Mixed Islands System Biome. Yet the former biome is not necessarily better protected since it contains most of Asia between 55°N and the Arctic Circle and much of Europe, while the Mixed Island System Biome contains only the Macronesian Islands and Ryukyu Islands (totaling about 17,820 square kilometers) Also, summaries of the coverage of biomes and biogeographical provinces by established protected areas tell little about the quality of management of these areas or the real protection afforded to ecosystems and species within them.

Protected areas have been established in all but 1 of the 14 biomes, although the number of areas and the total area protected vary greatly. Only the Lake Systems Biome within the Neotropical Realm has no protected areas. (See Table 6.7.) Other biomes are of concern because they have very few protected areas or have less than 1,000 square kilometers protected. (See Figure 6.2.)

Of the biogeographical provinces, 15 have no protected areas, and 30 have five or fewer protected areas *and* an area of less than 1,000 square kilometers protected. Some small provinces, though, are well protected. Eight provinces have less than 1,000 square kilometers protected but more than five protected areas.

This rough assessment of the state of protection of the world's biotic regions reveals that a number of provinces are poorly protected and thus require attention. Of course, the fragility of the biome type, its species richness, and the threats to it must also be considered in any decision to protect an area.

The main concerns at the 1982 World Congress on National Parks (66) were to identify gaps in protected area coverage, and to develop effective management and support for existing protectorates. The Congress made recommendations, in the Bali Action Plan. These prompted the IUCN and the World Wildlife Fund (WWF) to help protected-area managers and others develop regional plans for the Indomalayan, Afrotropical, and Neotropical Realms. The regional plans, which will be updated every six years, list candidate sites for the protected area system, species needing attention in particular areas, and national and international initiatives needed for existing protected areas.

Although the Udvârdy classification of biogeographical provinces is a valuable tool at the global scale, finer-grained classifications are needed to adequately protect the many ecological types within or spreading across province boundaries. Badly needed national and regional efforts are now underway. The Wildlife Institute of India, for instance, has designed an Indian biogeographical classification to inventory its protected area coverage (67). Similar national or regional analyses, in much greater detail, have been devised for New Zealand, Australia, Peru, Costa Rica, the United States, and several other countries. The best analyses are those in which several sets of data were used to determine conservation priorities. In Brazil, for example, over 30 mapped sets of biological information were combined to determine the best areas to establish new parks and reserves. While this system needs refining, it shows a new level of sophistication in determining ways a nation can best conserve its biological heritage.

The ecosystem approach to assessing protected area coverage does not necessarily protect all species. Planners must also make species cross-checks. Thus, when a given type of environment is being considered for protection, the areas chosen should ideally include the rarest species of the region. For example, among remaining Javan swampy lowland forests, the most valuable choice would be the forest area containing the few remaining Javan rhinoceroses.

The Corbett Action Plan for the Indomalayan Realm assesses the adequacy of protected area coverage from several viewpoints (68). At the national level, the Plan calls for a map of the major habitats and their faunal communities and inventories of key species in each biogeographic unit and protected area. The Plan suggests that this information form the basis for new management priorities and plans for expansion. At the international level, the Plan recommends that IUCN review protected areas within the Indomalayan Realm and create a data base on the Realm. The Plan urges governments to collaborate on a biogeographical classification system for use throughout the Realm.

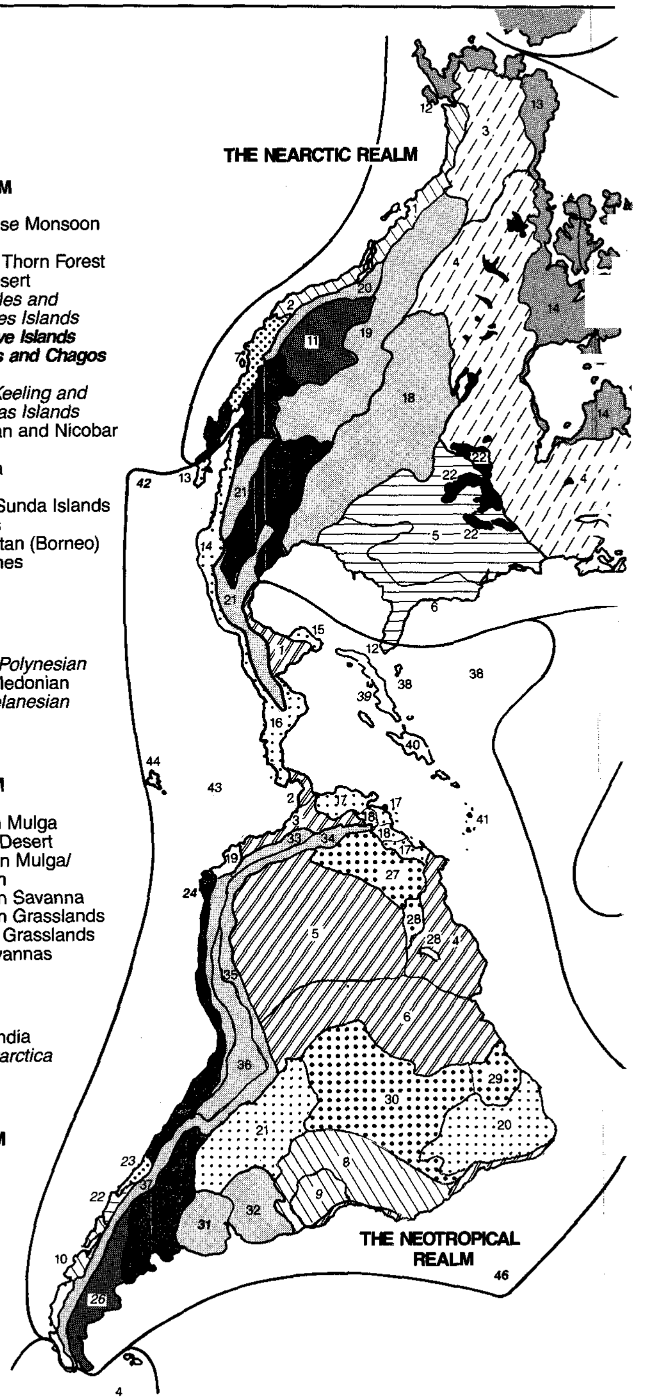
## Managing Protected Areas

If all the desired maps and inventories could be made, scientists still would not know how much of any given ecosystem could assure its survival and that of its species. The 10-percent target suggested in IUCN's Bali Action Plan can be misleading and does not allow for the great variation in species richness from one part of the world to another. Some experts, therefore, have recommended

# Figure 6.3 Realms, Biomes, and Biogeographical Provinces of the World

## Realms and Biogeographical Provinces

Use of ***bold face italics*** indicates provinces with no protected areas. Use of *italics* only indicates provinces with five or fewer protected areas and where less than 1,000 $km^2$ are protected.




### THE NEARCTIC REALM

1. Sitkan
2. Oregonian
3. Yukon taiga
4. Canadian taiga
5. Eastern forest
6. Austroriparian
7. Californian
8. Sonoran
9. Chihuahuan
10. *Tamaulipan*
11. Great Basin
12. Aleutian Islands
13. Alaskan tundra
14. Canadian tundra
15. ***Arctic Archipelago***
16. ***Greenland tundra***
17. Arctic desert and ice cap
18. Grasslands
19. Rocky Mountains
20. Sierra-Cascade
21. Madrean-Cordilleran
22. Great Lakes

### THE PALEARCTIC REALM

1. Chinese Subtropical Forest
2. Japanese Evergreen Forest
3. West Eurasian Taiga
4. East Siberian Taiga
5. Icelandian
6. Subarctic Birchwoods
7. Kamchatkan
8. British Islands
9. Atlantic
10. Boreonemoral
11. Middle European Forest
12. Pannonian
13. *West Anatolian*
14. Manchu-Japanese Mixed Forest
15. Oriental Deciduous Forest
16. Iberian Highlands
17. Mediterranean Sclerophyll
18. Sahara
19. *Arabian Desert*
20. Anatolian-Iranian Desert
21. Turanian
22. Takla-Makam-Gobi Desert
23. Tibetan
24. Iranian Desert
25. Arctic Desert
26. Higharctic Tundra
27. Lowarctic Tundra
28. *Atlas Steppe*
29. Pontian Steppe
30. Mongolian-Manchurian Steppe
31. Scottish Highlands
32. Central European Highlands
33. Balkan Highlands
34. Caucaso-Iranian Highlands
35. Altai Highlands
36. Pamir-Tian-Shan Highlands
37. *Hindu Kush Highlands*
38. Himalayan Highlands
39. *Szechwan Highlands*
40. Macronesian Islands
41. *Ryukyu Islands*
42. ***Lake Ladoga***
43. *Aral Sea*
44. ***Lake Baikal***

### THE AFROTROPICAL REALM

1. Guinean Rain Forest
2. Congo Rain Forest
3. Malagasy Rain Forest
4. West African Woodland/savanna
5. East African Woodland/savanna
6. Congo Woodland/savanna
7. Miombo Woodland/savanna
8. South African Woodland/savanna
9. Malagasy Woodland/savanna
10. *Malagasy Thorn Forest*
11. Cape Sclerophyll
12. Western Sahel
13. Eastern Sahel
14. Somalian
15. Namib
16. Kalahari
17. Karroo
18. Ethiopian Highlands
19. Guinean Highlands
20. Central African Highlands
21. East African Highlands
22. South African Highlands
23. ***Ascension and St. Helena Islands***
24. *Comores Islands and Aldabra*
25. *Mascarene Islands*
26. ***Lake Turkana (Rudolf)***
27. *Lake Ukerewe (Victoria)*
28. ***Lake Tanganyika***
29. *Lake Malawi (Nyasa)*

### THE INDOMALAYAN REALM

1. Malabar Rainforest
2. *Ceylonese Rainforest*
3. Bengalian Rainforest
4. ***Burman Rainforest***
5. Indochinese Rainforest
6. South Chinese Rainforest
7. Malayan Rainforest
8. Indus-Ganges Monsoon Forest
9. Burma Monsoon Forest
10. Thailandian Monsoon Forest
11. Mahanadian
12. Coromandel
13. Ceylonese Monsoon Forest
14. Deccan Thorn Forest
15. Thar Desert
16. *Seychelles and Amirantes Islands*
17. ***Laccadive Islands***
18. ***Maldives and Chagos Islands***
19. *Cocos-Keeling and Christmas Islands*
20. Andaman and Nicobar Islands
21. Sumatra
22. Java
23. Lesser Sunda Islands
24. Celebes
25. Kalimantan (Borneo)
26. Philippines
27. *Taiwan*

### THE OCEANIAN REALM

1. Papuan
2. *Micronesian*
3. Hawaiian
4. *Southeastern Polynesian*
5. *Central Polynesian*
6. New Caledonian
7. *East Melanesian*

### THE AUSTRALIAN REALM

1. Queensland Coastal
2. Tasmanian
3. Northern Coastal
4. Western Sclerophyll
5. Southern Sclerophyll
6. Eastern Sclerophyll
7. Brigalow
8. Western Mulga
9. Central Desert
10. Southern Mulga/ Saltbush
11. Northern Savanna
12. Northern Grasslands
13. Eastern Grasslands and Savannas

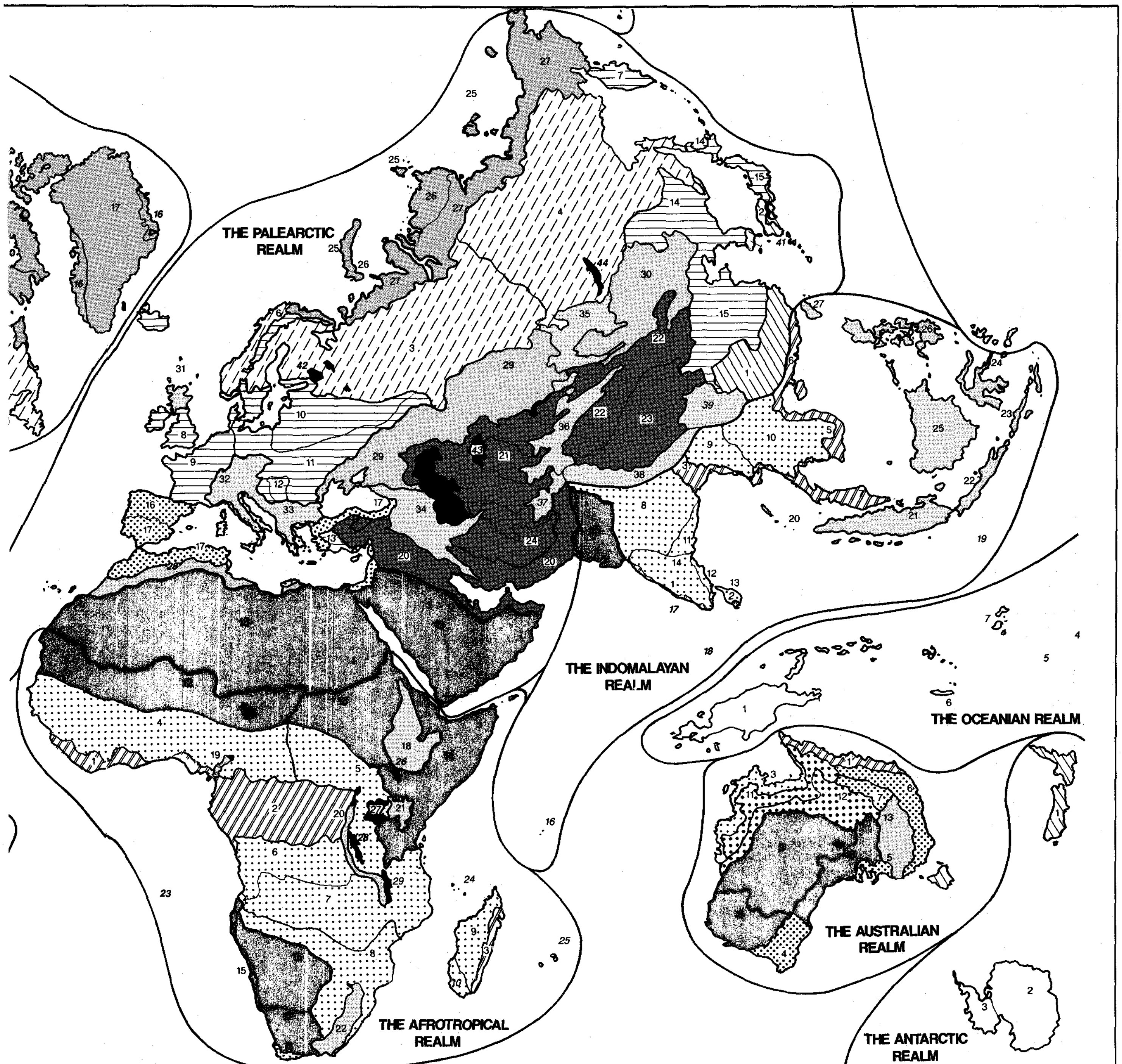
### THE ANTARCTIC REALM

1. Neozealandia
2. Maudlandia
3. Marielandia
4. *Insulantarctica*

### THE NEOTROPICAL REALM

1. *Campechean*
2. Panamanian
3. Colombian Coastal
4. Guyanan
5. Amazonian
6. Madeiran
7. Serra do mar
8. Brazilian Rain Forest
9. *Brazilian Planalto*
10. Valdivian Forest
11. Chilean Nothofagus
12. Everglades
13. Sinaloan
14. *Guerreran*
15. Yucatecan
16. Central American
17. Venezuelan Dry Forest
18. Venezuelan Deciduous Forest
19. Equadorian Dry Forest
20. Caatinga
21. Gran Chaco
22. *Chilean Araucaria Forest*
23. *Chilean Sclerophyll*
24. ***Pacific Desert***
25. Monte
26. *Patagonian*
27. Llanos
28. Campos Limpos
29. Babacu
30. Campos Cerrados
31. ***Argentinian Pampas***
32. Uruguayan Pampas
33. Northern Andean
34. Colombian Montane
35. Yungas
36. Puna
37. Southern Andean
38. Bahamas-Bermudan
39. *Cuban*
40. Greater Antillean
41. Lesser Antillean
42. ***Revilla Gigedo Island***
43. *Cocos Island*
44. Galapagos Islands
45. *Fernando de Noronja Island*
46. ***South Trinidade Island***
47. ***Lake Titicaca***

**Note:** This map is based on work by M.D.F. Udvârdy to define geographical units for conservation purposes, thus combining the distribution of species by realms with the distribution of ecosystems. Delimitation on a map of this scale inevitably involves gross generalization. No judgment is made on the percentage of each of the provinces protected.




**The Major Biomes**

- Tropical Humid Forests
- Sub-Tropical and Temperate Rainforests or Woodlands
- Temperate Broadleaf Forests or Woodlands and Sub-Polar Deciduous Thickets
- Temperate Needleleaf Forests or Woodlands
- Evergreen Sclerophyllous Forests, Scrub or Woodlands
- *Tropical Dry or Deciduous Forests (including Monsoon Forests) or Woodland*
- Tropical Grasslands and Savannas
- Temperate Grasslands
- Warm Deserts and Semi-Deserts
- Cold Winter (Continental) Deserts and Semi-Deserts
- Tundra Communities and Barren Arctic Deserts
- Mixed Mountain and Highland Systems with Complex Zonation
- Mixed Island Systems
- River and Lake Systems

**Sources:**
1. Adapted from UNESCO, "Conserving the World's Ecosystems," *Ecology in Action: A Poster Exhibit* (UNESCO, Paris, 1981).
2. IUCN, 1985, Reference 63.

## Table 6.6 Protected Areas in South America, 1985

| Country | Size of Country (km²) | Population (1985 est.) | No. of Protected Areas | Total Area Protected (hectares) | Percent of Country | Hectares Protected per 1,000 People |
|---|---|---|---|---|---|---|
| Argentina | 2,776,643 | 30,564,000 | 29 | 2,594,351 | 0.93 | 85 |
| Bolivia | 1,098,575 | 6,371,000 | 12 | 4,707,690 | 4.29 | 739 |
| Brazil | 8,511,968 | 135,564,000 | 50 | 11,894,302 | 1.40 | 88 |
| Chile | 756,943 | 12,074,000 | 64 | 12,737,360 | 16.83 | 1,055 |
| Colombia | 1,138,907 | 28,714,000 | 30 | 3,958,750 | 3.48 | 138 |
| Ecuador | 455,502 | 9,380,000 | 12 | 2,627,365 | 5.77 | 280 |
| French Guiana | 90,000 | 73,000 | 0 | 0 | 0.00 | 0 |
| Guyana | 214,969 | 953,000 | 1 | 11,655 | 0.05 | 12 |
| Paraguay | 406,750 | 3,681,000 | 9 | 1,120,538 | 2.75 | 304 |
| Peru | 1,285,215 | 19,698,000 | 11 | 2,407,642 | 1.87 | 122 |
| Suriname | 163,820 | 353,000 | 9 | 582,400 | 3.56 | 1,650 |
| Uruguay | 186,925 | 3,012,000 | 6 | 28,778 | 0.15 | 10 |
| Venezuela | 912,047 | 18,386,000 | 34 | 7,388,912 | 8.10 | 402 |
| **Total** | **17,998,264** | **268,823,000** | **267** | **50,059,743** | **3.78[a]** | **186[b]** |

**Notes:**
a. Mean percentage for all countries' total area.
b. Mean number of hectares protected for total population of all countries.
**Source:** Adapted from International Union for Conservation of Nature and Natural Resources, 1985, Reference 62.

## Table 6.7 Protected Areas by Biome and Realm, 1985

| Biome and Realm | Number of Areas | Total Area (hectares) |
|---|---|---|
| **Tropical Humid Forests** | | |
| Afrotropical | 44 | 8,905,733 |
| Indomalayan | 122 | 5,092,774 |
| Australian | 53 | 7,776,347 |
| Neotropical | 61 | 17,277,197 |
| Total | 280 | 39,052,051 |
| **Subtropical/Temperate Rainforests/Woodlands** | | |
| Nearctic | 18 | 8,129,505 |
| Palaearctic | 48 | 1,742,994 |
| Australian | 26 | 904,976 |
| Antarctic | 145 | 2,783,281 |
| Neotropical | 38 | 8,848,838 |
| Total | 275 | 22,409,594 |
| **Temperate Needle-Leaf Forests/Woodlands** | | |
| Nearctic | 53 | 30,321,679 |
| Palaearctic | 122 | 8,463,690 |
| Total | 175 | 38,785,369 |
| **Tropical Dry Forests/Woodlands** | | |
| Afrotropical | 240 | 48,673,552 |
| Indomalayan | 238 | 10,420,406 |
| Australian | 10 | 934,272 |
| Neotropical | 93 | 5,501,447 |
| Total | 581 | 65,529,677 |
| **Temperate Broad-Leaf Forests** | | |
| Nearctic | 82 | 1,890,216 |
| Palaearctic | 400 | 9,631,346 |
| Neotropical | 1 | 5,415 |
| Total | 483 | 11,526,977 |
| **Evergreen Sclerophyllous Forests** | | |
| Nearctic | 6 | 52,010 |
| Palaearctic | 122 | 3,374,156 |
| Afrotropical | 41 | 1,620,967 |
| Australian | 301 | 6,918,823 |
| Neotropical | 5 | 38,795 |
| Total | 475 | 12,004,751 |
| **Warm Deserts/Semi-Deserts** | | |
| Nearctic | 22 | 3,962,948 |
| Palaearctic | 7 | 616,534 |
| Afrotropical | 57 | 23,783,085 |
| Indomalayan | 35 | 1,628,854 |
| Australian | 33 | 10,165,383 |
| Neotropical | 7 | 1,446,751 |
| Total | 161 | 41,603,555 |
| **Cold-Winter Deserts** | | |
| Nearctic | 15 | 657,128 |
| Palaearctic | 57 | 12,854,167 |
| Neotropical | 4 | 36,700 |
| Total | 76 | 13,547,995 |
| **Tundra Communities** | | |
| Nearctic | 20 | 107,924,951 |
| Palaearctic | 8 | 7,247,904 |
| Antarctic | 11 | 258,334 |
| Total | 39 | 115,431,189 |
| **Tropical Grasslands/Savannas** | | |
| Australian | 12 | 2,041,393 |
| Neotropical | 18 | 7,011,403 |
| Total | 30 | 9,052,796 |
| **Temperate Grasslands** | | |
| Nearctic | 25 | 387,751 |
| Palaearctic | 22 | 805,408 |
| Australian | 34 | 670,163 |
| Neotropical | 9 | 70,516 |
| Total | 90 | 1,933,838 |
| **Mixed Mountain Systems** | | |
| Nearctic | 81 | 8,321,078 |
| Palaearctic | 231 | 8,071,815 |
| Afrotropical | 38 | 5,104,626 |
| Neotropical | 86 | 11,037,282 |
| Total | 436 | 32,534,801 |
| **Mixed Island Systems** | | |
| Palaearctic | 9 | 52,142 |
| Afrotropical | 4 | 23,033 |
| Indomalayan | 177 | 10,426,372 |
| Oceanian | 51 | 4,108,584 |
| Neotropical | 26 | 1,190,599 |
| Total | 267 | 15,800,730 |
| **Lake Systems** | | |
| Nearctic | 7 | 444,713 |
| Palaearctic | 1 | 18,300 |
| Afrotropical | 2 | 55,100 |
| Neotropical | 0 | 0 |
| Total | 10 | 518,113 |
| **Biogeographical Classification Unknown** | 132 | 7,866,578 |
| **Total** | **3,510** | **427,598,014** |

**Source:** International Union for Conservation of Nature and Natural Resources (IUCN), 1985, Reference 62.

20 percent or more for some biomes, such as tropical forests (69).

As for how large individual protected areas must be to maintain the species within them, the theory of island biogeography suggests that no reduced area, however well protected, can ultimately retain all its original species when surrounded by other land uses. But the larger the reserve, the slower and less severe the species loss will be. In crude terms, a single reserve containing 10 percent of the original area may support just 50 percent of the original species present. A study of 19 nature reserves in East Africa concluded that, in the absence of active management such as reintroductions, even the largest reserves would lose most of their large species within a few centuries (70).

An interesting 20-year experiment on "minimum critical area" of reserves is under way in the Brazilian Amazon north of Manaus. Here, the Brazilian government and the World Wildlife Fund are trying to determine how wildlife survives in forest reserves of different size—from 1 to 1,000 hectares—that are surrounded by agricultural land. Already it is obvious that species diversity in the very small plots deteriorates rapidly and such plots are almost worthless as reserves. It will take at least 20 years to gauge the success of the bigger reserves (71). Given the rapid cutting of tropical forests, however, most conservationists recommend establishing many large reserves now.

If adequate protected-area coverage is achieved, proper management will be the key to success. Today, management is excellent in some countries and negligible in others. Some national parks are overrun with farmers, hunters, and timber-cutters. Accordingly, many of the recommendations of the Bali Action Plan and regional action plans call for better training of managers, strengthened management policy and government conservation agencies, and the creation of management plans for individual reserves.

Many recent studies of wildlife conservation call for increased support for biological data centers. IUCN's Conservation Monitoring Center in Cambridge, England, is a principal focal point for this kind of information, though its budget is limited. More local or national data bases are needed, such as those being developed by several Latin American countries.

One category of protected area—the Biosphere Reserve—can potentially serve nearly the whole range of functions of IUCN's ten categories. Ideally, these reserves consist of core areas that receive strict protection, and other zones in which people live and work, usually in farming and forestry. In these reserves, research on both undisturbed and exploited ecosystems is conducted along with environmental education, training, and international scientific exchanges. As of early 1985, 243 biosphere reserves had been established in 65 countries (72).

Biosphere reserves are an important element in UNESCO's Man and the Biosphere Program (MAB), which adopted an Action Plan for Biosphere Reserves in December 1984. This plan contains 35 recommendations to be carried out by governments and international organizations, mostly from 1985 to 1989. The actions would expand the reserve network, improve research conducted within reserves, and improve management of the reserves so that they serve all intended purposes. If all these actions are carried out, biosphere reserves might become the most important component of the world's protected-area system.

## RECENT DEVELOPMENTS

### U.S. STRATEGY ON BIOLOGICAL DIVERSITY

Conservationists around the world are concerned about the rapid loss of biological diversity in the tropics. But tropical countries themselves lack adequate resources to handle the problem, so help from other countries is essential. Recognizing its major role in foreign assistance, the U.S. Government sponsored its first international conference on biological diversity in November 1981 to evaluate the world's wildlife conservation efforts.

In 1983, the U.S. Congress amended the Foreign Assistance Act of 1961, giving the government a legal mandate to help developing countries conserve their genetic resources. The amendments were known collectively as the International Environment Protection Act of 1983. It directed federal agencies to draft a comprehensive government strategy for conserving biological diversity in the Third World. Over the next year, a task force of 12 government agencies, chaired by the U.S. Agency for International Development (U.S. AID), consulted with experts from government, industry, academia, and environmental and policy groups. The resulting *U.S. Strategy on the Conservation of Biological Diversity* (73), submitted to Congress in February 1985, makes U.S. development assistance programs the focus of the government's plan. It calls for U.S. AID and the multilateral development banks to change the way they review the environmental impacts of their projects and to refuse to fund projects that destroy key ecosystems. The 67 public and private actions recommended in the interagency document include policy changes, support for education, institution strengthening, more research, and better management of protected areas. Critics have objected that the actions proposed appear as options rather than programs with funding: that the government presented a study, not a strategy as Congress requested. Currently, U.S. AID is preparing a detailed plan for directing its own activities.

Meanwhile, legislation has been introduced in the U.S. Congress "to amend the Foreign Assistance Act of 1961 to protect biological diversity in developing countries." Among major provisions are the allocation of $10 million annually to be used directly for conserving biological diversity, much of it through U.S. AID. U.S. AID is directed to help developing countries survey and protect critical ecosystems and establish and maintain protected areas, working whenever possible with private and voluntary organizations that would receive at least $3 million of the $10 million allocated.

Closely related and parallel to the biological diversity effort is a government initiative on tropical forests. Legislation recently introduced in Congress directs the U.S. Government to put more dollars into forest conservation projects worldwide. The initiative also earmarks government money for non-governmental conservation organizations.

### NATIONAL CONSERVATION STRATEGIES

In the late 1970s, IUCN, UNEP, and WWF developed a global strategy for conserving the world's biological resources. Their 1980 report, *The World Conservation Strategy: Living Resource Conservation for Sustainable Development* (74), links conservation with successful development and emphasizes priorities for national action, including the formulation of national conservation strategies. Currently, some 40 countries have started or completed such national strategies, including Australia, Malaysia, Nepal, Senegal, Zambia, Madagascar, Italy, Norway, the United Kingdom, and Belize. Wildlife conservation is an important element in these strategies.

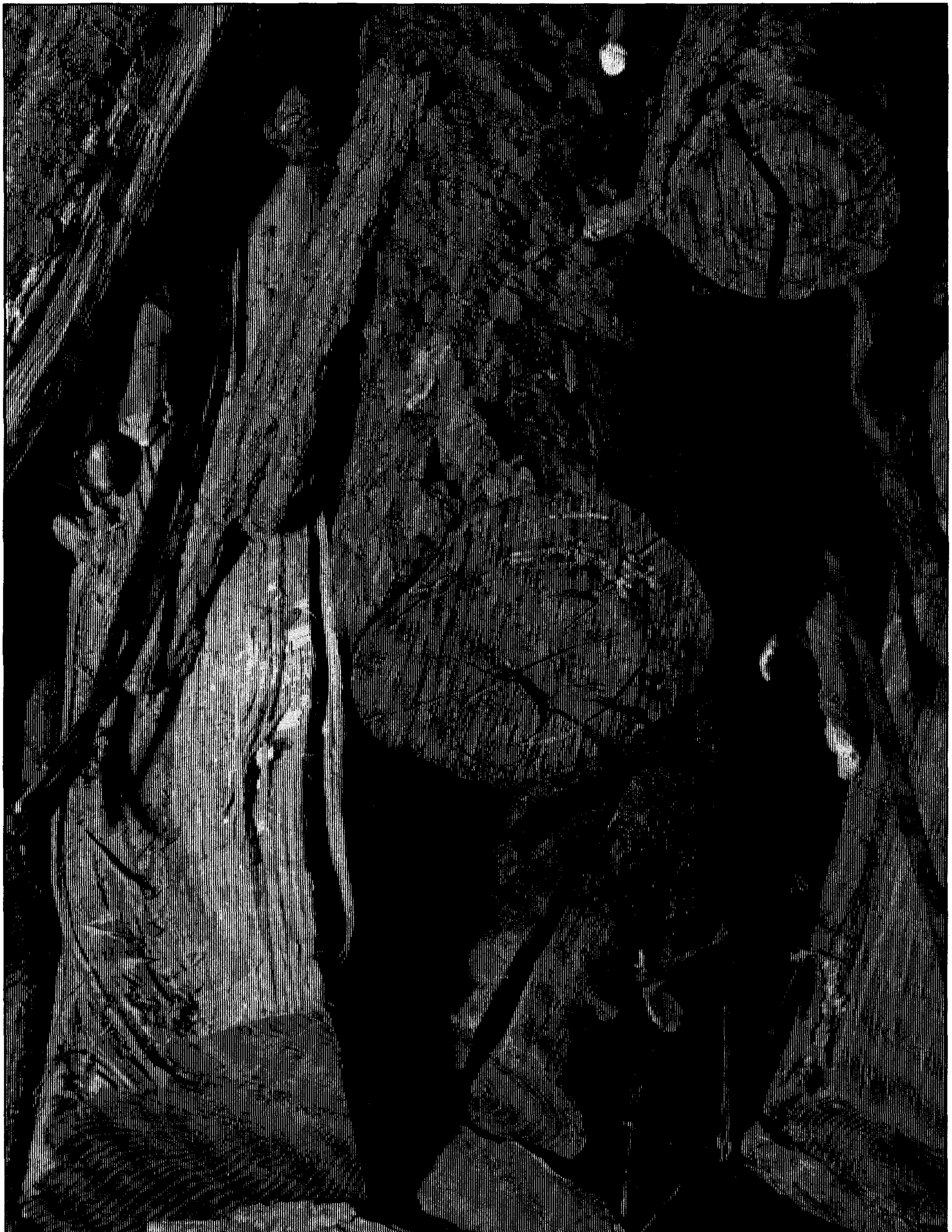
The national strategies necessarily have varied widely in how they were developed, which institutions were involved, and how closely a particular strategy was linked to other national efforts such as economic development plans. In about half of the countries, participation in preparing a national conservation strategy has been broad, including representatives of government, business, academia, conservation organizations, and other sectors. The rest typically involve only a few government officials. In many countries, public understanding of wildlife and other resource issues has increased dramatically. Nigeria, for example, whose prior conservation activity had been small and local, assembled some 400 people from all over the country to discuss the national conservation strategy and launch a draft document.

In June 1986, an international conference on conservation and development will bring 300 decisionmakers and professionals to Ottawa, Canada, to review the success and effectiveness of *The World Conservation Strategy* and the national strategies already written or now being developed. Conferees will also discuss the most effective ways to develop and implement national strategies and how these efforts can better integrate conservation and development.

## References and Notes


1. N. Myers, *The Sinking Ark* (Pergamon Press, Oxford, England, 1979), p. 5.
2. N. Myers, *A Wealth of Wild Species* (Westview Press, Boulder, Colorado, 1983).
3. M.L. Oldfield, *The Value of Conserving Genetic Resources* (U.S. Government Printing Office, Washington, D.C., 1984), pp. 91–143.
4. *Ibid.*, p. 91.
5. *Op. cit.* 3, p. 145.
6. World Resources Institute (WRI), *Tropical Forests: A Call for Action*, Vol. 1 (WRI, Washington, D.C., 1985) p. 5.
7. W.J. Brill, "Nitrogen Fixation: Basic to Applied," *American Scientist* Vol. 67, pp. 458–465 (1979).
8. P.H. Raven, *et al.*, *Biology of Plants*, Third Edition (Worth Publishers, Inc., New York, 1981), p. 297.
9. V.H. Heywood, Ed., *Flowering Plants of the World* (Oxford University Press, London and New York, 1978).
10. P.R. Ehrlich and A.H. Ehrlich, *Extinction* (Random House, New York, 1982), p. 17.
11. E. Mayr, *Populations, Species and Evolution* (Harvard University Press, Cambridge, Massachusetts, 1973).
12. *Op. cit.* 1, pp. 15–17.
13. P.H. Raven, *Research Priorities in Tropical Biology* (National Research Council, Washington, D.C., 1980), p. 35.
14. *Ibid.*
15. *Op. cit.* 1, p. 17.
16. T.L. Erwin, "Tropical Forest Canopies: The Last Biotic Frontier," *Bulletin of the Entomological Society of America*, Vol. 29, No. 1, pp. 14–19 (1983).
17. Food and Agriculture Organization (FAO), *Tropical Forest Resources* (FAO, Rome, 1982), p. 80.
18. *Op. cit.* 10, p. 133.
19. N. Myers, *The Primary Source* (W.W. Norton and Co., New York, 1984), p. 46.
20. *Op. cit.* 13.
21. F.R. Fosberg, "The Deflowering of Hawaii," *National Parks and Conservation Magazine*, Vol. 49, No. 10, pp. 4–10.
22. *Op. cit.* 1, p. 26.
23. *Op. cit.* 1, p. 24.
24. C.H. Dodson and A.H. Gentry, "Flora of the Rio Palenque Science Center," *Silbyana*, Vol. 4, pp. 1–6 (1978).
25. International Union for Conservation of Nature and Natural Resources (IUCN), *IUCN Directory of Coral Reefs of International Importance, Vol. 2, Indian Ocean* (IUCN Conservation Monitoring Center, draft, Cambridge, England (1985), p. 43.
26. The Latin American/Caribbean Regional Conservation Data Center, the Nature Conservancy International Program, Washington, D.C., 1985.
27. Organization for Economic Cooperation and Development (OECD), *Report on the State of the Environment* (OECD, Paris, 1985), p. 142.
28. C. Robbins, U.S. Fish and Wildlife Service, Laurel, Maryland, 1985 (personal communications.)
29. International Union for Conservation of Nature and Natural Resources (IUCN), *The IUCN Plant Red Data Book* (IUCN, Morges, Switzerland, 1978), p. 8.
30. International Council for Bird Preservation, *Endangered Birds of the World* (Smithsonian Institution Press, Washington, D.C., 1981).
31. *Op. cit.* 26.
32. International Union for Conservation of Nature and Natural Resources (IUCN), Conservation Monitoring Center, unpublished data supplied by the Species Conservation Monitoring Unit, October 1985.
33. A.V. Hall, *et al.*, "Threatened Plants in Southern Africa," *Biological Conservation*, Vol. 28, pp. 5–20 (1984).
34. Council on Environmental Quality, *Environmental Trends* (U.S. Government Printing Office, Washington, D.C., 1981), p. 18.
35. *Op. cit.* 27, p. 142.
36. *Op. cit.* 1, p. 36.
37. *Op. cit.* 1, p. 34.
38. C.M. Schoenwald-Cox, *et al.*, Ed., *Genetics and Conservation* (The Benjamin/Cummings Publishing Co., London, 1983), p. 427.
39. K. Hillman, African Wildlife Foundation, Nairobi, Kenya, 1985 (personal communication).
40. Wildlife Trade Monitoring Unit, *A Perception of the Issue of High Trade Volume* (Conservation Monitoring Center, Cambridge, England, 1984).
41. D. Mack and R.A. Mittermeier, Eds., *The International Primate Trade, Vol. 1, Legislation, Trade and Captive Breeding* (TRAFFIC U.S.A., World Wildlife Fund-U.S. Primate Program, and International Union for Conservation of Nature and Natural Resources/Primate Specialist Group, Washington, D.C., 1984), pp. 1–83.
42. P.H. Raven, Missouri Botanical Garden, St. Louis, Missouri, 1985 (personal communication).
43. D. Simberloff, "Are We on the Verge of Mass Extinction in Tropical Rain Forests?" (unpublished monograph, July 1983).
44. L. Thomas, U.S. Fish and Wildlife Service, Washington, D.C., 1985 (personal communication).
45. *Op. cit.* 27, p. 154.
46. O.H. Frankel and M.E. Soule, *Conservation and Evolution* (University of Cambridge Press, New York and London, 1981).
47. C.F. Ponce del Prado, "Inca Technology and Ecodevelopment: Conservation of the Vicuñas in Pampa Galeras," in *National Parks, Conservation, and Development*, J.A. McNeely and K.R. Miller, Eds. (Smithsonian Institution Press, Washington, D.C., 1984), pp. 575–580.
48. *Op. cit.* 27, p. 140.
49. E. Matthews, "Global Vegetation and Land-Use: New High-Resolution Data Bases for Climate Studies," *Journal of Climate and Applied Meteorology*, Vol. 22, pp. 474–487 (1983).
50. A. Sommer, "An Attempt at an Assessment of the World's Tropical Moist Forests," *Unasylva*, Vol. 28 (112–113), pp. 5–24 (1976); and *op. cit.* 17.
51. *Op. cit.* 17.
52. *Op. cit.* 19, p. 156.
53. C. Caufield, *In the Rainforest* (Alfred A. Knopf, New York, 1985), p. 40.
54. *Op. cit.* 19, p. 176.
55. N. Shelton, "Logging Versus the Natural Habitat in the Survival of Tropical Forests," *AMBIO*, Vol. 14, No. 1, pp. 39–41 (1985).
56. *Op. cit.* 27, p. 146.
57. International Union for Conservation of Nature and Natural Resources (IUCN), Conservation Monitoring Center, *The*

*IUCN Mammal Red Data Book*, Part I (IUCN, Gland, Switzerland, 1982), p. xiii.
58. J. Newby, "The Role of Protected Areas in Saving the Sahel," in *National Parks, Conservation, and Development*, J.A. McNeely and K.R. Miller, Eds. (Smithsonian Institution Press, Washington, D.C., 1984), pp. 130–135.
59. *Op. cit.* 34, p. 18.
60. *Op. cit.* 27, p. 149.
61. *Op. cit.* 27, p. 151.
62. International Union for Conservation of Nature and Natural Resources (IUCN), *The United Nations List of National Parks and Protected Areas* (IUCN, Gland, Switzerland, and Cambridge, England, 1985).
63. M.D.F. Udvârdy, *A Classification of the Biogeographical Provinces of the World* (International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, 1975).
64. B.P. Hayden, *et al.*, "Classification of Coastal and Marine Environment," *Environment Conservation*, Vol. 11, No. 3, pp. 199–207 (1984).
65. This analysis is based on J. Harrison, International Union for Conservation of Nature and Natural Resources (IUCN), Conservation Monitoring Center, *Study of the Status and Trends of In-Situ Conservation of Biological Diversity Worldwide*, draft submission to the U.S. Congress, Office of Technology Assessment (IUCN, Cambridge, England, 1985).
66. The proceedings of this Congress were published in J.A. McNeedy and K.R. Miller, *National Parks, Conservation, and Development* (Smithsonian Institution Press, Washington, D.C., 1984), pp. 130–135.
67. J. Mackinnon, "Outline of Methodology for Preparation of Review of the Protected Areas System of the Indomalayan Realm" (unpublished, 1985).
68. International Union for Conservation of Nature and Natural Resources (IUCN), Commission on National Parks and Protected Areas, *The Corbett Action Plan for Protected Areas of the Indomalayan Realm* (IUCN, Gland, Switzerland, 1985).
69. *Op. cit.* 1, p. 222.
70. M.E. Soule, *et al.*, "Benign Neglect: A Model of Faunal Collapse in the Game Reserves of East Africa," *Biological Conservation*, Vol. 15, pp. 259–272 (1979).
71. *Op. cit.* 53, pp. 78–79.
72. United Nations Educational, Scientific and Cultural Organization (UNESCO), Program on Man and the Biosphere, *Action Plan for Biosphere Reserves* (UNESCO, Paris, 1985), p. 2.
73. U.S. Agency for International Development (USAID), *U.S. Strategy on the Conservation of Biological Diversity: An Interagency Task Force Report for Congress* (USAID, Washington, D.C., 1985).
74. International Union for Conservation of Nature and Natural Resources (IUCN), *World Conservation Strategy: Living Resource Conservation for Sustainable Development* (IUCN, Gland, Switzerland, 1980).



# 7. Energy

Energy is sometimes referred to as the lifeblood of our societies, for fuels are used to drive virtually all human activities. In the industrialized world commercial fuels—fuels that are traded commercially—dominate the energy scene. Fossil fuels—oil, gas, and coal—account for about 90 percent of global commercial energy requirements, and of these oil is the most important (1).

By contrast, in the Third World a combination of commercial and non-commercial woodfuels (that is, firewood and charcoal) and other biofuels (animal and crop residues) are the main source of energy for some 2.5 billion people, or roughly half the world's population (2). At the global level, more people depend on wood than on any other single energy source for their daily energy needs. The Director General of the U.N. Food and Agriculture Organization (FAO) has pointed out that "In this respect, wood can still be counted the world's most important fuel" (3).

## CONDITIONS AND TRENDS

In 1984, commercial (4) energy consumption throughout the world totaled 7,201.6 million metric tons of oil equivalent (Mtoe). (See Table 7.1.) (One toe contains the same energy as about 7.33 barrels of crude oil.) The two biggest consumers of all this energy are the United States (25 percent) and the Soviet Union (18.4 percent). On a per capita basis, Canada is the biggest consumer at 8.8 toe per person, followed by the United States (7.8 toe), the USSR (4.8 toe), Eastern Europe (4.1 toe), and Western Europe (about 3.4 toe). In contrast, the developing countries use only about 0.5 toe per person (5).

There was a steady and rapid growth in world energy consumption after World War II—for almost three decades—as economies prospered on cheap and plentiful supplies of oil. During the last 10–15 years, however, this trend has been disrupted, as Figure 7.1 shows, and the picture has become more complicated and less predictable.

### PATTERNS AND TRENDS IN ENERGY CONSUMPTION AND PRODUCTION

Policies and patterns of consumption have changed dramatically, primarily in response to the oil price rises of 1973–74 and 1979–80. As a result, energy systems based on renewable sources have received increased attention in both the developed and developing worlds. The only renewables making a significant contribution at present are biomass and hydropower, but important advances have been made with wind energy conversion systems (WECS), solar collectors, and photovoltaic systems, which will be examined in detail in a later edition of *World Resources*.

There are marked differences in the patterns and trends of energy consumption among different groups of

**Table 7.1 Commercial Energy Consumption by Region, Key Countries, and Fuels, 1984**
*(million metric tons of oil equivalent)*

| | Oil | Natural Gas | Coal | Hydro-electric | Nuclear | Total | Percent |
|---|---|---|---|---|---|---|---|
| North America | 791.4 | 505.8 | 466.2 | 154.6 | 101.3 | 2019.3 | 28.0 |
| Western Europe[a] | 591.0 | 190.1 | 256.7 | 107.0 | 104.6 | 1249.4 | 17.4 |
| Oceania[b] | 35.5 | 14.4 | 34.6 | 9.3 | | 93.8 | 1.3 |
| Japan | 214.6 | 33.1 | 64.0 | 19.8 | 30.6 | 362.1 | 5.0 |
| USSR | 447.8 | 439.4 | 357.0 | 53.0 | 25.0 | 1322.2 | 18.4 |
| Eastern Europe[c] | 98.7 | 77.0 | 274.2 | 7.2 | 7.5 | 464.6 | 6.5 |
| Developing Countries[d] | 579.7 | 139.3 | 260.4 | 111.0 | 13.2 | 1103.6 | 15.3 |
| China | 85.8 | 10.8 | 466.5 | 23.5 | 0.0 | 586.6 | 8.1 |
| **World Total** | **2844.5** | **1409.9** | **2179.6** | **485.4** | **282.2** | **7201.6** | **100.0** |
| Percent | 39.5 | 19.6 | 30.3 | 6.7 | 3.9 | 100.0 | |

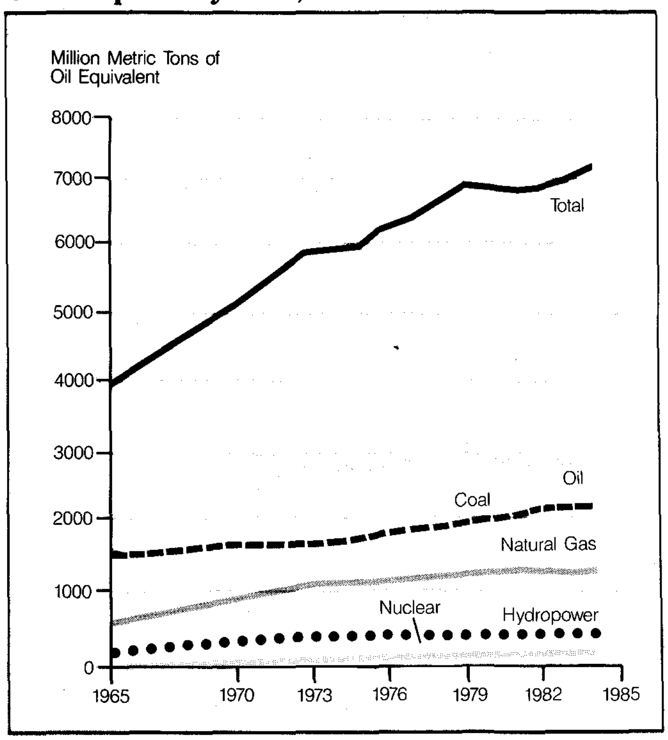
**Notes:**
a. Western Europe includes Austria, Belgium, Cyprus, Denmark, Federal Republic of Germany, Finland, France, Gibraltar, Greece, Iceland, Republic of Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Yugoslavia.
b. Oceania includes Australia, New Zealand, Papua New Guinea, Southwest Pacific Islands.
c. Eastern Europe includes Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania.
d. Developing Countries includes all Latin American, African (including South Africa), South Asian, Southeast Asian, and Middle Eastern countries.
**Source:** British Petroleum, 1985, Reference 1.

countries, as well as in the specific energy issues that face them. Key developments in different regions are highlighted below.

## Western Industrialized Countries

The Western industrialized countries include: Western Europe, North America, Japan, Australia, and New Zealand. Total primary energy consumption in Western Europe and North America has changed in strikingly similar ways during the last 20 years, as Figure 7.2 shows. In both regions there was a decline in consumption after the oil price rises in 1973–74 and 1979–80. As a result, the 1984 level of consumption for each of these regions was similar to what it had been ten years before.

**Figure 7.1 Global Commercial Primary Energy Consumption by Fuel, 1965-84**




**Sources:**
1. British Petroleum, 1985, Reference 1.
2. British Petroleum, 1985 (personal communication).

## Eastern Europe and the Soviet Union

This group of countries includes the Soviet Union and the Eastern European countries of Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, and Romania. There are significant differences between the energy situation in the Soviet Union and Eastern Europe, but their close economic and political ties mean that they do function as a distinct regional grouping in energy terms. A key energy development for these countries in recent years has been the stagnation of Soviet oil production. This is critically important to Eastern Europe as well as to the Soviet Union itself because the Eastern European countries, with the exception of Romania, depend on the Soviet Union for about 90 percent of their oil.

Eastern Europe's increasing demand for oil, combined with the Soviet Union's constrained supply, is expected to make energy trade "the most important and problematic aspect of Soviet-East European economic relations in the second half of this decade" (6). The Eastern European dependence on Soviet energy supplies seems likely to escalate, binding these countries closer to the USSR in economic terms.

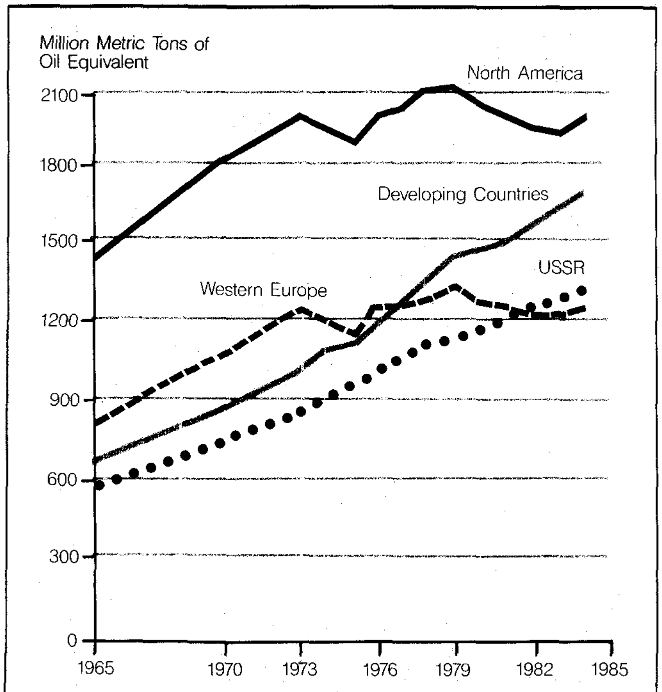
Given the constraints on Soviet fuel production (problems have been encountered in increasing the contribution of coal and nuclear power as well as oil), improved energy efficiency is an obvious priority. However, as Figure 7.2 shows, Soviet energy consumption has been increasing steadily, in contrast to the trend in the West, due in part to lower fuel prices in the USSR.

## Developing Countries

As in the Soviet Union, commercial energy consumption in the developing world has risen during the last two decades, despite the oil price shocks. And it is expected to continue to rise because of the comparatively low level of per capita consumption in these countries and the likelihood of further major increases in population.

During the last decade, oil-importing developing countries have felt the impact of two energy crises

**Figure 7.2 Primary Energy Consumption by Region, 1965-84**




**Sources:**
1. British Petroleum, 1985, Reference 1.
2. British Petroleum, 1985 (personal communication).

simultaneously. For the last few years, the increased price of oil has proved a severe burden to their economies, particularly with non-oil commodity prices remaining fairly constant (see Figure 7.3). In 1981, low- and middle-income oil-importing countries were spending 61 percent and 37 percent, respectively, of their export earnings on oil imports (7); the international debts of these countries increased by a factor of six between 1973 and 1982 (8). At the same time most of these countries have been experiencing a serious decline in the availability of their principal domestic source of energy—fuelwood. (See "Focus on: Fuelwood Scarcity," below.)

## OIL

In 1984, oil still accounted for 40 percent of total commercial energy consumption (9). Nevertheless, this figure is lower than the 47.4 percent share which oil held in 1973 (10). The drop was due, in part, to the economic recessions following the oil price rises since 1973 (see Figure 7.4), partly to improvements in the efficiency with which oil is used, and partly to the substitution of other fuels for oil.

Although oil prices have recently been declining in dollar terms—as an internationally traded commodity, oil is priced in U.S. dollars—the recent strength of the dollar relative to other currencies means that for Western Europe and the developing countries the price of oil has remained high.

During the last 20 years, there have been major changes in the share of oil consumption among the First, Second, and Third Worlds, as is clear from Table 7.2.

### Western Industrialized Countries

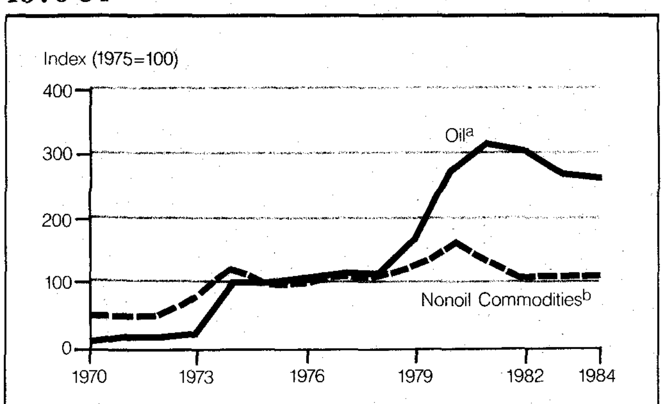
The share of oil in total energy consumption of International Energy Agency (IEA) member countries (11) dropped from 51 percent in 1973 to 43 percent in 1983, and their oil intensity (total oil consumption divided by Gross Domestic Product [GDP]) fell by 30.4 percent over the same period.

About 20 percent of the oil consumed by the Organization for Economic Cooperation and Development (OECD) countries in 1982 (12) was used in the residential sector (13), 18.7 percent in industry, 53.2 percent in transport, and the remainder in the service sector and agriculture (14). The proportion of oil used in the residential and industrial sectors has declined considerably since the first OPEC price rises, primarily because of energy efficiency improvements and fuel substitution.

In the *residential* sector, oil use declined by about 30 percent between 1972–73 and 1982 (15). It appears that 40–45 percent of the reduction resulted from fuel conversions away from oil or investments in efficiency measures, all of which would continue for a long time even if oil prices fall, while the remainder arose from rapid—and reversible—cutbacks in consumption in response to the price increases (16).

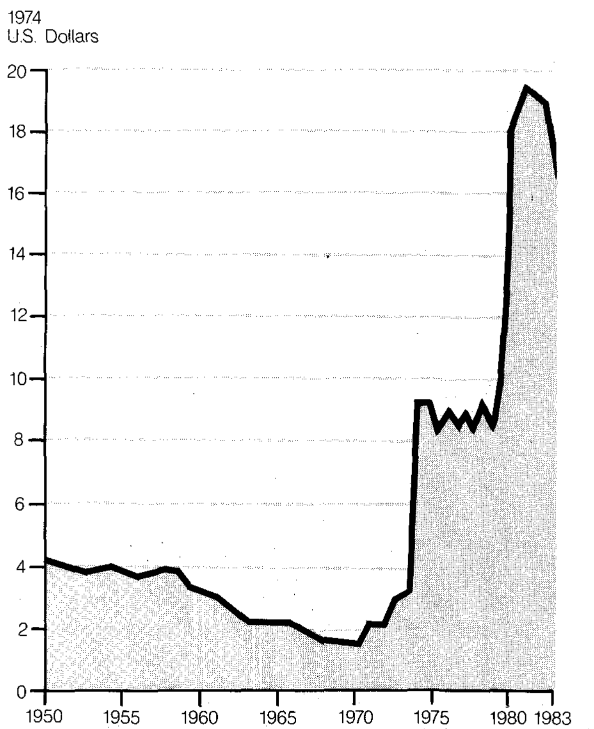
Total final oil consumption by *industry* in the IEA countries fell by 27 percent in this period (1973–82) (17). Considerable fuel substitution (from oil to coal) has taken place in the energy-intensive industries—notably iron and steel and cement—which were able to switch fuels relatively easily (18). Oil substitutions also occurred in another energy-intensive industry, paper and pulp, which increased its use of biomass (wood wastes and tree

**Figure 7.3 Oil and Nonoil Commodity Prices, 1970-84**




**Notes:**
a. Average dollar price of internationally traded oil.
b. Average dollar price of 33 primary commodities, weighted by each commodity's share in developing countries' exports.
**Source:** The World Bank, *The World Bank Annual Report 1985* (The World Bank, Washington D.C., 1985) p. 40.

**Figure 7.4** Price of Oil (Saudi Arabian Light Crude), 1950-83




**Source:** P. Odell, *Draining the World of Energy* (Center for International Energy Studies, Rotterdam, 1984) p. 8.

stumps), particularly in North America and Scandinavia and in some cases switched from oil to coal (19).

More than half the total oil consumption is accounted for by the *transport* sector, whose share has grown during the last decade or so. During the last ten years, oil has constituted 99 percent of the fuels consumed for transport purposes in the western industrialized countries. Road transport has accounted for almost 80 percent of this oil consumption; air transport is the other major user.

The impact of the oil price hikes was felt in this sector also (see Table 7.3), so that although transport's share of total oil consumption increased, the absolute level of consumption fell.

**Table 7.2 Oil Consumption by Region and Percent of World Consumption, 1973 and 1984**
*(million metric tons of oil equivalent)*

| | 1973 | Percent | 1984 | Percent |
|---|---|---|---|---|
| North America | 901.7 | 69.9 | 791.4 | 57.4 |
| Western Europe | 748.9 | | 591.0 | |
| Japan | 269.1 | | 214.6 | |
| Oceania | 34.8 | | 35.5 | |
| Soviet Union | 325.7 | 14.3 | 447.8 | 19.2 |
| Eastern Europe | 75.1 | | 98.7 | |
| Developing Countries (including China) | 442.7 | 15.8 | 665.5 | 23.4 |
| **World Total** | **2,798.0** | **100** | **2,844.5** | **100** |

**Source:** British Petroleum, 1984 and 1985, Reference 1.

**Table 7.3 Oil Consumption in the Transport Sector in IEA Countries, 1973–82**
*(million metric tons of oil equivalent)*

| | 1973 | 1975 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| Cars, Buses, & Trucks | 516.4 | 527.9 | 586.0 | 620.7[a] | 615.2 | 594.7 | 581.8 | 582.7 |
| Total | 697.4 | 697.7 | 757.8 | 801.8 | 806.5[a] | 782.2 | 756.9 | 746.5 |

**Note:** a. Year of peak consumption
**Source:** International Energy Agency (IEA), *Fuel Efficiency of Passenger Cars* (OECD, Paris, 1984), p. 24.

Considerable improvements have been made in the fuel efficiency of new cars, primarily through reductions in car weight and greater use of new fuel-efficient technologies. The change in oil consumption trends shown in Table 7.3 is also partly due to reductions in the average mileage driven per car. The combination of these factors resulted in a drop of 21.4 percent between 1973 and 1982 in the average petrol (gasoline) consumption per car in the IEA countries; however, this was offset by a 34.7 percent increase in the number of vehicles over the same period. Thus, the net result was an increase in petrol consumption of 5.9 percent between 1973 and 1982.

## Eastern Europe and the Soviet Union

Oil consumption in the Soviet Union increased without interruption between 1965 and 1983. This increase was due in large measure to the Soviet Union's self-sufficiency in oil at the time; production rose from 429.0 Mtoe in 1973 to 616.3 Mtoe in 1983 (20). Consequently, when oil prices in the rest of the world quadrupled in 1973–74, prices in the Soviet Union were not affected. In the early 1980s, however, the rate at which oil production was increasing slowed markedly. In 1984, production fell for the first time since World War II as a result of production difficulties, especially in the new oil fields in Siberia, where output is hampered by extremes of climate and the high costs of oil extraction and long-distance transport. These problems lead many observers to doubt whether the Soviet Union will be able to increase oil production significantly above the current level (21).

Unlike the western industrialized countries, the Soviet Union has not needed to reduce its oil consumption because of dependency on foreign supplies. On the other hand, its oil exports are extremely important in foreign exchange terms. In 1983, about 64 percent (some $14 billion) of Soviet hard currency earnings came from oil sales. For this reason, it is clearly in the Soviet Union's economic and strategic interest to economize on its oil consumption.

An important element of Soviet policy has been to substitute natural gas for oil, but so far the impact on oil consumption has been limited. Electricity generation is one area in which the use of oil could be reduced. Oil's share of fuel use by power stations rose from 7.5 percent in 1960 to 35.2 percent in 1980, but recent policy shifts have given priority to reversing this trend (22).

Car ownership is very low in the Soviet Union compared with the West, and in 1980 there were only 8.5 million cars in use. Thus, there is the potential for a major increase in car ownership and a corresponding increase in oil use. Realizing this the Soviets have launched a major program aimed at building metros (subways) in all major cities, partly because this will discourage greater use of cars and partly because the metro is seen as the quickest, cleanest, and cheapest mode of urban transportation (23).

The oil situation in the Soviet Union has been significantly different from that in Eastern Europe, where oil consumption has declined slightly since 1980, from 102.6 to 98.7 Mtoe (24). This decline is probably because of the economic difficulties these countries have been experiencing and their lack of foreign exchange for purchasing oil either on the world market or from the Soviet Union.

### Developing Countries

Third World oil consumption has increased markedly in the last 30 years or so, and between 1973 and 1984 the developing world's share of oil consumption rose by almost half. (See Table 7.2.) During the last five years, however, the absolute level of oil consumption barely increased at all as oil prices grew and economic growth rates fell well below those experienced in the 1970s.

Generally speaking, the main use of oil in developing countries is for transport, and the second most important sector is industry. In 1981, for example, the proportion of oil used for transport in India, Kenya, Sri Lanka, and Brazil ranged between 43.2 percent (Sri Lanka) and 56.2 percent (Brazil), while the proportion consumed by industry ranged between 25.2 percent (Brazil) and 30.6 percent (India) (25).

When economic activity increases again in the developing countries, oil consumption can be expected to resume its upward trend, particularly for transport purposes. The current low level of personal travel and vehicle ownership in the Third World allows ample room for expansion. In these countries, the growth of markets, especially the traffic in manufactured goods and trade items, is an essential element of the entire development process. However, in some countries, particularly those with sugar production such as Zambia, it may be practicable to use alcohol fuels from biomass instead of oil, as Brazil has done.

### Global Prospects For Oil

With the present excess of supply capacity, and the increased contribution of non-OPEC countries, it appears that the threat of further oil supply disruptions or major price hikes has receded, at least for a few years. (See "Recent Developments," below). It is widely believed that the current downward trend in oil prices will continue during the next few years. Oil is not expected to return to its 1982 price level until some time during the 1990s. Exactly when prices will start to rise again—and the market tighten—depends to a large extent on the demand factors reviewed above.

On the supply side, overall production in the West, including the United States and the North Sea, is expected to decline steadily between now and the turn of the century; production in the Soviet Union is not likely to increase significantly and might even decline. It is generally expected, therefore, that before the turn of the century there will be a return to increased reliance on Middle East sources unless governments vigorously pursue policies to encourage fuel substitution, oil conservation, and indigenous oil exploration. The latter is particularly important in the Third World, where exploration efforts have lagged.

By the time the world's crude oil supplies have been depleted, the total amount of oil used is expected to range from 1.6 to 2.4 trillion barrels (26, 27, 28). If these estimates are correct, production could continue at about the present level until some point in the second quarter of the next century, but it would then fall off quite rapidly.

## NATURAL GAS

Natural gas is the world's third largest commercial fuel (after oil and coal), accounting for 19.6 percent of global energy consumption in 1984 (29). This figure represents a slight increase over its 1973 share of 18 percent (30). North America (36 percent) and Eastern Europe and the Soviet Union (36.5 percent) consumed the largest amounts, with Western Europe (13.5 percent) and the developing countries (10.6 percent) consuming considerably smaller shares (31).

This global picture masks major regional changes that have been taking place during the last 10–15 years. Consumption in the United States declined from 562.5 Mtoe in 1973 to 458.0 Mtoe in 1984, resulting in a decline in production over the same period (32). Nevertheless, natural gas still accounted for 25 percent of U.S. energy consumption in 1984, three quarters of which was used in industry and the residential sector in roughly equal amounts (33).

The trend in the rest of the world has been in the opposite direction. Consumption increased by about 90 percent between 1973 and 1984, from 503.6 to 951.9 Mtoe (34). In the USSR, gas consumption more than doubled between 1973 and 1984, from 198.8 Mtoe to 439.4 Mtoe, amounting to one-third of Soviet energy consumption (35). The Soviet Union replaced the United States as the world's largest producer in 1983. In Western Europe consumption increased from 129.9 Mtoe in 1973 to 190.1 Mtoe in 1984. In the European OECD countries, industry consumes the largest share (43 percent); within this sector the chemical industry is the major user, as it is in the United States (36). Natural gas has been an important substitute for oil in the domestic and service sectors in most of these countries. Some European countries (the United Kingdom, Norway, and the Netherlands) have significant reserves of their own, but most others have to import gas.

The Soviet Union exports considerable quantities of natural gas to both Eastern and Western Europe. The importation and use of Soviet gas by Western Europe have generated much controversy within the NATO countries, centering around the implications these gas imports have on the long-term security of the Western Alliance (37).

In the Third World, natural gas is not an important fuel at present due to a lack of infrastructure and exploration; it constitutes less than 1 percent of the total commercial energy consumed. However, many developing countries—particularly in South and Southeast Asia—have indigenous gas reserves that, if developed, could be an important source of energy given the necessary distribution network.

At the end of 1984, proved reserves of natural gas (87,000 Mtoe) were slightly smaller than oil reserves (96,000 Mtoe) (38). However, since gas consumption is considerably less than oil consumption, the lifetime of the gas reserves at current levels of use (60 years) is almost twice that of oil reserves (34 years). Forty-three percent of proved gas reserves are in the USSR, 26 percent in the Middle East (particularly Iran), 8.5 percent in North America, 6.1 percent in Western Europe, 5.5 percent in Africa (3.2 percent in Algeria), and 4.9 percent in Asia and Australia (mainly in Indonesia and Malaysia) (39).

In the IEA countries as a whole, the current production level is likely to be maintained at least until the turn of the century. Production is expected to continue increasing in the Soviet Union for some time to come, and new fields will be opened up in many Third World countries. At the global level, therefore, it should be possible to maintain the current level of consumption for several decades.

Natural gas resources have not been as extensively investigated as oil resources. Until recently, gas has been found as a by-product of the search for crude oil; so far there has been little systematic prospecting for coal-based natural gas. In addition to conventional natural gas resources, which account for almost all the proved reserves, there are various kinds of "unconventional" resources. Most of the unconventional gas production is expected to take place in North America (40). Some types of unconventional sources—tight gas, Devonian shale, and coal seam methane—may play a significant role in U.S. gas supply within the next 20–30 years (41).

## COAL

In the aftermath of the first oil price rises, Western Europe and North America began to look at coal as a possible replacement for imported oil. By 1984, however, coal's share of world energy consumption had increased only slightly above what it was in 1973, from 28.2 percent to 30.3 percent (42). Coal's contribution to the Soviet energy budget actually fell from 36 percent in 1973 to 27 percent in 1984, reflecting the fairly steady level of coal output and the increasing use of natural gas and oil (43). On the other hand, coal consumption in China increased by a remarkable 60 percent, making the People's Republic one of the three major producers of coal in the world, along with the United States and the Soviet Union (44). Together these three countries account (in roughly equal amounts) for about 60 percent of world production.

Domestic coal prices vary considerably from country to country, according to productivity levels, whether the coal is obtained from deep or surface (opencast) mines, the amount of government subsidy, etc. On the international market, world steam coal prices have been falling during the early 1980s—from $60 per metric ton in 1980 to about $45 per metric ton in late 1984 (both in 1982 dollars), as a result of lower than expected demand. Between now and the turn of the century, prices are not expected to rise much; they could even remain constant in real terms, partly because of new producer countries entering the market. International trade in coal is currently dominated by Australia, the United States, and South Africa, but new low-cost suppliers such as Colombia, Botswana, and Indonesia will gradually increase the diversity and competitiveness of the trade.

Like natural gas, coal requires a considerable infrastructure before it can be used on a significant scale, and partly for this reason coal's share of total primary energy consumption in developing countries tends to be less than in many industrialized countries. There are notable exceptions, however. Apart from China, coal is also the major fuel in India, accounting for 41 percent of all commercial energy consumption and 26 percent of total energy consumption (including non-commercial biomass fuels) in 1979 (45). Coal is expected to make an increasing contribution to power generation in the developing countries; its share of the fuel mix is projected by the World Bank to rise from 29.9 percent in 1980 to 35.6 percent in 1995 (46).

Coal is the major fuel used in electricity generation in the OECD countries, and in 1983 about two-thirds of all coal use was for this purpose. Of the remainder, three-quarters was consumed in the industrial sector, primarily by the iron and steel industry, with a significant amount in the residential sector as well (47). Further substitution of coal for oil can be expected in industry, but this is likely to be a slow process, and little substitution is expected in the transport or residential/service sectors in the foreseeable future.

### Coal Supply Prospects

World coal deposits are vast—an order of magnitude greater than oil and gas resources—and it is unlikely that new discoveries will substantially alter the present estimate of 10 trillion ($10^{13}$) metric tons (48). If all this coal were recoverable, and consumption continued at present rates, several thousand years' supply would be available. Not surprisingly, therefore, the Western industrialized countries see coal as a substitute for oil (and to a lesser extent, natural gas). Such figures, however, give no indication of the amount of recoverable coal, allowing for technical and economic constraints.

A more meaningful assessment of the future availability of coal resources is provided by the data in Table 7.4, which show that there are 484 billion metric tons of coal that can be exploited within the next 20 years. This supply would last more than 100 years at the current rate of consumption. Thirty-seven percent of this coal is in the OECD countries (primarily the United States, which has 21 percent of the world's total), 23 percent is in the USSR, 19 percent in Asia (mostly China, 15 per-

**Table 7.4 World Coal Resources and Reserves by Type of Coal**
*(billion metric tons)*

| | Bituminous Coal and Anthracite | Sub-bituminous Coal | Brown Coal/ Lignite |
|---|---|---|---|
| Proved Amount-in-Place 1[a] | 920 | 260 | 340 |
| Proved Recoverable Reserves 1[b] | 515 | 166 | 265 |
| Accessible Coal in Significant Coalfields 2[c] | 358 | 25 | 101 |

**Notes:**
a. "Proved Amount-in-Place" is defined as the fraction of total resources that has been carefully measured and assessed as being exploitable in a particular country under present and expected local economic conditions with existing available mining technology.
b. "Proved Recoverable Reserves" represents the fraction of proved reserves (Amount-in-Place) that can be recovered (actually mined) under the same economic and technological limits as described above.
c. The category "Accessible Coal in Significant Coalfields" gives estimates of the amount of coal from particular coalfields that is considered capable of playing a significant part in world coal supply and trade within the next 20 years. Thus, it excludes, for example, virgin fields remote from ports, railways, and population centers.

**Sources:**
1. World Energy Conference (WEC), *Survey of Energy Resources* (WEC, London, 1983).
2. International Energy Agency (IEA) Coal Research, *Concise Guide to World Coalfields* (IEA, London, 1983).

cent), 8 percent in Poland, 6.5 percent in Africa (almost entirely South Africa), and 1.3 percent in Central and South America (mainly Colombia and Mexico). The fact that the United States, along with the OECD as a whole, have large reserve estimates is partly because these countries — in contrast to most developing nations — are well-explored and nearly all their resources have been identified. Such vast reserves of coal mean that its use is not likely to be limited by supply constraints. If coal does not increase its share of the market significantly, it will be due either to lack of infrastructure or to coal's environmental impacts. (See Box 7.1.)

## PRIMARY ELECTRICITY

Fossil fuels generate the vast majority of the world's electricity, but since the 1960s there has been a gradual shift toward other sources of electricity. In the industrialized countries, nuclear power has been the preferred choice, at least until recently, while hydropower's contribution has been increasing steadily in the Third World.

### Nuclear Power

Nuclear power's contribution has increased dramatically in recent years, from 62.4 Mtoe in 1974 to 282.2 Mtoe in 1984 (49). (See Part IV, Table 8.3.) In 1984, nuclear power accounted for 3.9 percent of world primary energy consumption and 16 percent of electricity produced in the OECD countries. More than 90 percent of nuclear electricity production is in highly industrialized countries, primarily in North America (35.9 percent) and Western Europe (37.1 percent) (50). The size of nuclear generating capacity in the countries with the largest nuclear power programs is shown in Table 7.5.

**Table 7.5 Nuclear Power Plant Capacity in Key Countries, 1984**
*(gigawatts of electricity)*

| | |
|---|---|
| Belgium | 3.5 |
| France | 33.3 |
| Federal Republic of Germany | 16.1 |
| Spain | 4.8 |
| Sweden | 8.4 |
| United Kingdom | 10.7 |
| **Western Europe Total** | **83.8** |
| Canada | 10.0 |
| United States | 71.2 |
| Japan | 21.8 |
| Taiwan | 4.0 |
| USSR | 24.1 |
| **World Total** | **226.6** |

**Source:** U.S. Energy Information Administration, *Commercial Nuclear Power: Prospects for the United States and the Rest of the World* (U.S. EIA, Washington, D.C., 1985).

**Box 7.1 The Environmental Impacts of Fossil Fuels**

All fossil fuels affect the environment to some extent, but the impacts of coal production and use are potentially the most serious. Coal extraction operations tend to have greater aesthetic effects on the landscape, particularly surface (opencast) mining, whose share of total production has grown in recent years (1).

Coal combustion emits large quantities of sulfur dioxide, nitrogen oxides, soot, ash, and dust as well as heavy metals (the amounts depend on the quality of coal burned). If not controlled, these emissions translate directly into environmental damage: the acidification of lakes, damage to buildings and metal surfaces, reduced crop yields and forest declines. (See Part III, Chapter 12, "Multiple Pollutants and Forest Decline.") These impacts represent financial as well as environmental costs. For example, it has been estimated that the financial losses arising from forest decline in West Germany amount to more than $1 billion per year (2).

It is possible to eliminate most sulfur dioxide emissions from coal-fired power stations by installing flue gas desulfurization systems. However, several countries (e.g., the United Kingdom, United States, Czechoslovakia, and Poland) have not retrofitted these systems into existing plants because they feel that the benefits would not justify the costs. These countries also export much of their emissions abroad. New, less-polluting technologies, such as fluidized bed combustion, may also help alleviate acid deposition problems.

A third and relatively intractable environmental problem associated with coal combustion (and to a lesser extent, oil and gas) is the release of carbon dioxide and its buildup in the atmosphere. (See Chapter 10, "Atmosphere and Climate.") The increases in coal consumption traditionally embodied in long-term energy projections (see "Energy Projections," below) are big enough to lead to major climate modifications. At present the only known way of avoiding a warmer earth and rising sea levels is not to burn the coal in the first place. The climate factor, therefore, could be the ultimate constraint on coal use.

Another important class of pollutants arising from fossil fuel combustion is nitrogen oxides ($NO_x$). In most OECD countries, about half the man-made $NO_x$ emissions come from the transport sector (almost entirely from oil combustion) and the other half from industry and electricity generation (from oil, gas, and coal combustion) (3).

$NO_x$ emissions are thought to be a key contributor to acid deposition and its associated damage, particularly the forest declines noted in Europe and North America. (See Chapter 12, "Multiple Pollutants and Forest Decline.")

**References and Notes**

1. M. Chadwick and N. Lindman, *Environmental Implications of Expanded Coal Utilization* (Pergamon Press, Oxford, 1982), p. 21.
2. Federal Ministry for Research and Technology, Bonn, West Germany, 1985.
3. Organization for Economic Co-operation and Development (OECD), *The State of the Environment 1985* (OECD, Paris, 1985), p. 21.

In the foreseeable future, the rate at which new capacity is installed is expected to slow down in most countries, owing to a combination of developments in recent years, including increased capital costs, lower load forecasts, and environmental opposition. The main environmental concerns have been reactor safety issues, particularly following the Three Mile Island accident, the disposal of radioactive wastes (see Chapter 9, "Oceans and Coasts," for a discussion of constraints on ocean disposal), and the potential overlap between the civil and military applications of nuclear fission. (See "Energy Projections," below.).

Prospects for nuclear power are particularly bleak in the United States, where capital costs per kilowatt of installed capacity have increased by a factor of four in real terms for plants being completed around now (1983–87) compared with a typical plant completed in 1971 (51). In addition, construction times have doubled, and plant performance has remained generally mediocre. Consequently, nuclear power has become a far less attractive option in economic terms. No orders for new nuclear reactors have been placed since 1978, and the 13 orders that were placed between 1975 and 1978 were cancelled or deferred indefinitely (52). Few, if any, new orders are likely in the United States during the rest of this decade.

## Hydropower

World hydro-electricity consumption increased from 331.5 Mtoe in 1973 to 485.4 Mtoe in 1984, its share of total commercial energy production rising from 5.6 percent to 6.7 percent (53). North America and Western Europe consume more than 50 percent of this electricity, but their share of total consumption has been declining slightly (54). In the developing countries, on the other hand, consumption of hydro-electricity doubled from 57 Mtoe to 126.7 Mtoe between 1973 and 1984, increasing their share of world consumption from 17.2 percent to 26.1 percent during the same period (55).

In 1980, hydropower accounted for 40.8 percent of electricity production in developing countries, and this figure is expected to grow to 42.6 percent by 1995. (See Table 7.6 for a summary of hydropower development status by region.) The rate at which new projects are introduced will be constrained by cost factors, the lack of power markets near potential hydropower sources (56), and the need to take account of their potential for harmful environmental and social side effects (57).

One important side effect is the displacement of indigenous people from their traditional lands, often to poorer ones: 80,000 were displaced by the Aswan High Dam in Egypt, and 75,000 by the Lake Volta scheme in Ghana (58). Other effects include the spread of waterborne diseases such as schistosomiasis, the disruption of aquatic ecosystems, and major reductions in the flow of nutrient-rich silt to agricultural lands downstream which depend upon the silt for their fertility. Conversely, silt sometimes accumulates in the artificially created reservoirs instead, thereby sharply curtailing the dam's ability to generate electricity, as has happened, for example, to the Sanman Gorge Dam in China and Egypt's Aswan Dam (59).

## BIOMASS FUELS

In the industrialized countries, wood and other biomass fuels had almost ceased to be used as energy sources prior to the 1973 oil shock, but since then they have begun to make a comeback in some countries. In the United States, Norway, and Sweden, wood use for residential heating has nearly doubled from the low values of the mid–1970s, presently accounting for more than 10 percent of the market (60). Both Canada and the United States derive 3–4 percent of their primary energy from wood, most of which is used in their forest products industries (61).

It is in the Third World, however, that biomass fuels assume greatest importance (62). As noted earlier, the official statistics on energy consumption in these countries often do not include the contribution made by biomass fuels. They do not because the data on the use of these fuels are limited, are often of poor quality, and are not usually collected on a standardized basis over a period of several years. Data collection is made particularly difficult by the fact that a large proportion of the fuels consumed are not commercial and therefore do not have any recorded transactions. Nevertheless, surveys of various kinds have demonstrated that biomass fuels, particularly fuelwood, are usually a key source of energy in developing countries. The contribution of biomass in various low- and middle-income countries is shown in Table 7.7.

**Table 7.6 Hydropower Development Status by Region, 1982**

| Annual Technical Potential | West Africa | East Africa | South Asia | East Asia | Europe Middle East North Africa | Latin America Caribbean | 100-Country Total |
|---|---|---|---|---|---|---|---|
| **Potential Production (terawatt-hours)** | | | | | | | |
| Installed | 14 | 45 | 60 | 78 | 76 | 221 | 494 |
| Under Construction | 9 | 37 | 47 | 72 | 48 | 165 | 378 |
| Under Investigation | 48 | 85 | 90 | 790 | 47 | 563 | 1,623 |
| Remaining | 301 | 826 | 526 | 1,752 | 186 | 1,716 | 5,307 |
| Total | 372 | 993 | 723 | 2,692 | 357 | 2,665 | 7,802 |
| **Capacity (gigawatts)** | | | | | | | |
| Installed capacity | 3 | 9 | 14 | 26 | 19 | 51 | 122 |
| Under construction | 2 | 8 | 12 | 17 | 16 | 38 | 93 |
| Under investigation | 10 | 17 | 21 | 155 | 15 | 126 | 344 |
| Remaining | 70 | 182 | 124 | 356 | 50 | 335 | 1,117 |
| Total | 85 | 216 | 171 | 554 | 100 | 550 | 1,676 |

**Source:** The World Bank, 1984, Reference 46.

**Table 7.7 Percentage of Biomass in Total Energy Consumption of Selected Countries**

| Low Income Countries | Year | Percent | Middle Income Countries | Year | Percent |
|---|---|---|---|---|---|
| Burkina Faso[1] | 1980 | 94 | Costa Rica[4] | 1978 | 42 |
| Malawi[2] | 1980 | 94 | Philippines[3] | 1981 | 38 |
| Mali[1] | 1980 | 93 | Peru[4] | 1978 | 35 |
| Mozambique[2] | 1980 | 89 | Brazil[3] | 1981 | 34 |
| Sri Lanka[3] | 1981 | 75 | Colombia[4] | 1978 | 24 |
| Kenya[3] | 1981 | 68 | Chile[3] | 1980 | 18 |
| India[3] | 1979 | 42 | Portugal[3] | 1981 | 7 |

**Sources:**
1. Y. Lambert, *Energy Needs in West African Countries: Possible Contribution of Renewable Energy* (Energy Research Group, Ottawa, 1984).
2. J. Simoes, Ed., *SADDC: Energy and Development to the Year 2000* (Beijer Institute/Scandinavian Institute of African Studies, Sweden, 1984).
3. Leach *et al.*, 1985, Reference 78.
4. G. Sanchez-Sierra and L.A. Umana-Quesada, "Quantitative Analysis of the Role of Biomass Within Energy Consumption in Latin America", *Biomass*, 3, pp. 21-41, 1984.

In 1983, 1.63 billion cubic meters of wood were consumed, equivalent to about 6 percent of the world's commercial energy consumption (63). Estimates of the contribution of woodfuels to the total energy budget of developing countries vary from the neighborhood of 10 percent in a few higher income Latin American countries to more than 90 percent in poorer African countries (64, 65). (See Table 7.7.) Among the rural poor, fuelwood and other forms of biomass are usually the dominant or only fuels. Altogether some 2.5 billion people depend on them to meet their daily domestic energy requirements (66). A study by the FAO, covering 95 developing countries, found that fuelwood played a significant role in all of them (67). As many as 21 of these countries depend on fuelwood for more than 75 percent of their energy supplies (68).

In developing countries most fuelwood is used for domestic purposes, particularly in rural areas. The amount of fuel used by rural households varies considerably both among and within countries. Where local supplies are plentiful, consumption tends to be higher. For example, annual consumption figures of 1,100–2,865 kilograms (kg) per person have been reported in Nicaragua (69), and 1,636–2,600 kg of wood per person are used in some parts of Tanzania (70).

Where wood is scarce, however, the quantities consumed decrease considerably. People economize on the amount of wood they use by lighting smaller fires, quenching and re-using embers which would otherwise have been allowed to burn away, and positioning or sheltering fires more carefully. Surveys in Mali and Niger measured consumption ranging from 440 to 660 kg per person per year (71). Similar consumption levels have been found in areas of wood scarcity in India (72, 73), and even lower consumption levels exist in some areas.

It is often difficult to define how much of this household energy is being used for which purposes. The cooking fire may also serve as the only source of space heating, water heating, and—in many cases—lighting. It can also be the main social focus of family life, an insect repellent, odor suppressor, and defense against wild animals. The few reliable breakdowns of rural household energy consumption available show that cooking (including water heating) is usually the most important end-use, followed by space heating and lighting. Fuelwood sometimes meets all these requirements, but kerosene (or torches and candles) are often used for lighting.

Fuelwood (and charcoal) are also used for cooking and other domestic purposes in urban areas. In addition, however, certain industries—including baking, brewing, tobacco-curing, pottery, and brick and lime-making—consume significant amounts of woodfuels in some countries. In Sri Lanka, woodfuels supply about 57 percent of industrial energy demand, in Kenya 64 percent, and in Tanzania as much as 88 percent (74).

In many regions of the world, wood has become so scarce that people turn to other sources of biomass instead, such as dung and crop residues. The greatest use of biomass residues is found in the relatively treeless plains of Northern India, Bangladesh, and China, where crop residues and dung provide as much as 90 percent of household energy in many villages and a considerable proportion in urban areas, too (75).

## FOCUS ON: FUELWOOD SCARCITY

In 1983, the FAO published a study of fuelwood supplies in the Third World which showed that more than 100 million people were consuming amounts "below minimum requirements" for cooking and heating, etc. (76). In addition, nearly 1.3 billion people were in a deficit situation—and could meet their needs only by depleting wood reserves. (See Table 7.8.) More than 64 percent of these people lived in Asia. Shortages were most acute in the arid regions of Africa, in the mountainous areas of Asia, particularly the Himalayas, and on the Andean plateau in Latin America.

The future prospects are even more disturbing. The study's projections for the year 2000 suggest that, without immediate action to improve the situation, 3 billion people will either be unable to obtain their minimum energy needs or will be forced to consume wood faster than it is being grown (77). The FAO study is open to a number of criticisms, but the general thrust of its findings is widely accepted.

### Fuelwood Scarcity in Rural Areas

The pattern of fuelwood collection varies enormously from one region to another. Broadly speaking, however, a distinction can be drawn between situations where

**Table 7.8 Populations Experiencing a Fuelwood Deficit, 1980 and 2000[a]**
*(millions)*

| Region | 1980 | | | | 2000 | |
|---|---|---|---|---|---|---|
| | Acute scarcity | | Deficit | | Acute Scarcity or Deficit | |
| | Total Population | Rural Population | Total Population | Rural Population | Total Population | Rural Population |
| Africa | 55 | 49 | 146 | 131 | 535 | 464 |
| Near East and North Africa | | | 104 | 69 | 268 | 158 |
| Asia and Pacific | 31 | 29 | 832 | 710 | 1,671 | 1,434 |
| Latin America | 26 | 18 | 201 | 143 | 512 | 342 |
| Total | 112 | 96 | 1,283 | 1,052 | 2,986 | 2,398 |

**Note:** a. Total population and rural population (total population less that of towns with more than 100,000 inhabitants) in zones whose fuelwood situation has been classified.
**Source:** Adapted from Food and Agriculture Organization, 1983, Reference 67.

people live near forests and collect wood from them and those in which the wood comes from free-standing trees or bushes on relatively open land.

Village communities near forests can generally harvest fuelwood on a sustainable basis. Problems arise only when other factors intervene to deplete the forest resource. The major cause of deforestation is the clearance of forests to create new agricultural land. The reason may simply be a growing population, but changes in population distribution can also be important.

Other major causes of deforestation are logging and large-scale construction projects, such as dams or roads, developments which tend to bring further pressures in their wake as an area becomes more closely connected to population centers. These additional pressures, particularly land clearance for agriculture, may lead to the overexploitation and gradual receding of the forest, making fuelwood a scarce resource. Thus, rural fuelwood users are not so much the cause of deforestation as the victims of it (78).

Most rural families, however, live too far from forests to obtain their daily fuel needs from them. Consequently, they have to rely on the free-standing trees and bushes within walking distance from their homes for their fuel as well as for numerous other needs, such as building poles, fruit, shade, and fodder. If population densities in these areas remain low, it may be possible to satisfy the demand for fuelwood without damaging the local standing stock of trees. Where fuelwood is plentiful, usually only dead wood is collected since it is easier to cut, is lighter to carry, and burns better than green wood. Though branches may be lopped off, whole trees are rarely felled merely to provide fuel.

If the population increases, however, local supplies of dead wood may become scarce or inadequate, forcing people to spend more time searching for and collecting fuelwood. As good fuelwood becomes more difficult to obtain, people begin to economize in the way they use it. Nevertheless, population pressures may eventually be so great that people have no choice but to exploit the trees (by lopping off large branches or even chopping down whole trees) so that either they die or their productive capacity is severely degraded. Fuelwood consumption is not likely to be the only factor in this process, however, nor necessarily the most important one; livestock grazing and fodder gathering may also be major contributors to the stunting or killing of trees.

When demand exceeds the rate at which the trees are able to regenerate, people have to turn to tree roots, crop residues, dung, and other combustible biomass materials as replacements for or supplements to fuelwood.

The shift to other biofuels expands the amount of fuel available, but there are good reasons why residues are often turned to only as a last resort. Cow and buffalo dung produce a lot of smoke, which can be irritating to eyes and lungs; while most crop residues (such as cereal straw and lightweight stalks) demand more time and care in feeding and tending the fire than wood does. Dung and agricultural residues may also be serving a valuable role as fertilizers.

### The Impact of Urban Use

The majority of fuelwood is purchased in towns and cities. The wood or charcoal that urban household and industrial consumers buy is often carried or trucked in from rural areas, and the money they pay for it gives a strong incentive to both organized businesses and poor peasants to cut down living trees.

As a result of urban woodfuel demands, an expanding "ring of desolation" surrounds many cities, such as Dakar (Senegal), Ouagadougou (Burkina Faso), and Niamey (Niger). In addition to collection by the urban and peri-urban poor in the vicinity of towns and cities, a large proportion of the woodfuels consumed in urban areas is supplied by organized commercial operations that often truck the fuel in from far afield. Much of the wood is converted into charcoal first since it is lighter and easier to transport. Studies in Hyderabad, Kenya, and elsewhere have shown that wood supplies often come from about 100 kilometers away and charcoal from a few hundred kilometers (79).

Large areas of trees may be removed with little concern for the environmental costs since these do not affect the urban consumer directly. Urban demands for woodfuels and timber are the primary cause of deforestation in Southern Africa (80). On a global basis, urban consumption of wood may be more responsible for depleting rural fuelwood supplies than local consumption (81).

### Consequences and Responses

A decade ago, it was widely believed that fuelwood scarcity was a problem that would solve itself with time, as people gradually shifted toward the use of fossil fuels and electricity. However, the major increases in fossil fuel prices and the lack of progress in dealing with poverty in the Third World have led to a shift in attitudes.

Fuelwood scarcity has several harmful consequences. It causes increasing hardship to the rural poor, due to the large amount of time spent in collecting fuel. Thus, fuel gathering joins water collection as a source of daily drudgery, cutting into potentially productive time, especially for women. Ultimately, scarcity may also lead to health problems if people are forced to cook less or turn to less nutritious foods. The urban poor, on the other hand, may be faced with rising fuelwood prices, and even if other fuels become competitive, the poor often cannot afford the initial investment in the necessary gas or kerosene stoves.

Loss of tree cover can also have disastrous environmental consequences. Trees play a vital role in restoring soil fertility and maintaining soil structure, so their removal tends to be followed by loss of topsoil due to wind or water erosion, particularly in arid zones, mountains, and other fragile ecological areas. In certain circumstances, the switch from woodfuels to crop and animal residues can exacerbate the ecological damage arising from the loss of tree cover, leading to reductions in crop yields (82).

New initiatives aimed at alleviating the situation have focused primarily on two basic approaches — using fuelwood more efficiently and planting more trees (83).

Although simple and obvious in the abstract, these measures have proved to be surprisingly difficult to implement.

In the mid-1970s, as awareness of fuelwood problems increased, there was a great deal of interest in wood conservation through the development and dissemination of more efficient cookstoves. Laboratory findings that the traditional method of cooking over "three-stone fires" used only 3–10 percent of the useful energy led to considerable optimism that efficient cookstoves would result in major fuel savings—perhaps as much as 50 percent—and hence widespread adoption.

The experience of numerous stove programs has identified many obstacles to their extensive introduction—including technical, economic, and cultural factors (84, 85). Technical difficulties include serious discrepancies between laboratory and field performance and declining fuel efficiency due to rapid deterioration and breakage. The major economic barrier has been that stoves cost several dollars to buy (as much as $30 or more for certain types of stoves) in contrast to the open fire. Cultural barriers tend to arise from the fact that fires meet other needs, such as lighting and heating, as well as cooking, which the stoves are not designed to meet; in addition, the open fire is more adaptable than most stoves to variations in the size or number of pots. (See Box 7.2.)

In view of the limited scope for improving the efficiency with which fuelwood is used in the home, new sources of fuelwood (to replace those being depleted) or substitute fuels are essential in alleviating the problems of fuelwood scarcity. As with modern cooking stoves, the concern over fuelwood scarcity prompted programs to plant trees, but again many of them encountered unexpected problems (86).

Various factors such as legal constraints on tree cutting, no legal entitlement to the land on which the trees were to be grown, or simply low priority in the minds of the local people have hindered tree planting efforts. However, even if the barriers to tree planting are overcome and there is much greater local commitment and official support than in the past, it will be impossible in many areas to bring the supply of fuelwood into balance with the projected demand. Other energy sources, such as kerosene and bottled gas, will have to begin to replace fuelwood.

In many countries it may simply prove impossible to solve the fuelwood crisis through stove and tree-growing programs alone. Only when their incomes rise will the rural poor be able to buy efficient cook stoves, switch to alternative fuels, or find it unnecessary to cut down trees for sale to urban consumers. Problems arising from fuelwood scarcity can be fully and effectively dealt with only in the context of poverty-focused strategies for development.

## ENERGY USE PATTERNS IN THE FIRST WORLD

### Energy Efficiency

Since the first OPEC price rises, there have been significant improvements in the efficiency with which energy is used in all the major energy sectors—residential, service, transport, and industry—in the western industrialized countries.

In the *residential* sector, factors like higher levels of thermal insulation and weatherization (draft-stripping) of the "shells" of buildings and more efficient appliances (such as stoves and refrigerators) have reduced the amount of energy required to satisfy household needs. Thus, despite increases in room temperatures and the more widespread use in recent years of various appliances (e.g., freezers), energy use per dwelling has declined in most OECD countries, as Figure 7.5 shows.

### Box 7.2 "How Much Wood Would a Wood Stove Save, if a Wood Stove Could Save Wood?"

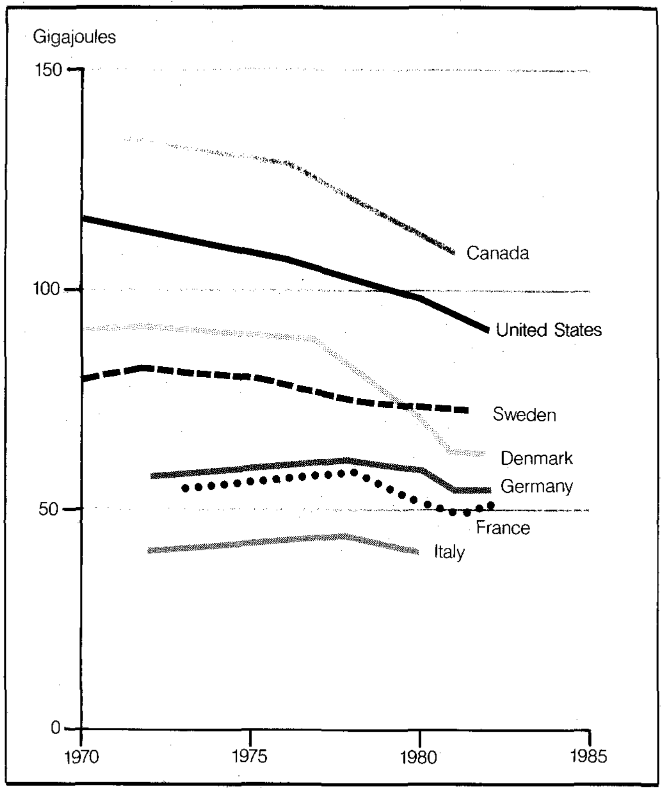
Many lessons have been learned from the problems encountered by earlier stove programs. Originally, many stove programs hoped to disseminate improved models that families could build themselves. More recently, as the technical demands of stove efficiency and durability have become more apparent, emphasis has shifted toward models that can be built by well-trained artisans at low cost. Metal stoves have proved to be more effective than mud stoves in certain situations because they are amenable to mass manufacture and careful quality control, and they also tend to last longer. A project in West Africa introduced a new metal stove that is achieving 30–35 percent average fuel savings relative to open fire cooking or use of the traditional metal stove of the region (1).

For a number of reasons, the potential of stoves to reduce fuelwood consumption appears to be limited largely to urban areas (2). Many people living in rural areas simply cannot afford to buy a stove. Most of them have less incentive to do so than the urban population because they gather rather than buy the wood and therefore would not save money by switching to a stove. In addition, the capability for mass-producing high quality metal stoves tends to exist primarily in urban areas, whereas short-life mud stoves may be the only option in many rural areas. For these and other reasons such as the inability of stoves to provide adequate lighting in certain circumstances (an important obstacle in rural areas of Kenya, Malawi, and West Bengal, for example), many experts no longer expect improved cooking stoves to make a major impact on fuelwood consumption at the national level (3,4). Nevertheless, they can produce benefits for some groups of people, and they may also have other advantages such as reducing smoke pollution (a serious health problem in relatively confined spaces) and fire hazards.

**References and Notes**


1. S. Strasfogel and G. Dechambre, *Bilan des Connaissance sur les Besoins en Bois de Chauffe: Resultats Techniques des Foyers Ameliores Metallique Mai Sauki* (Association Bois de Feu, Juillet, France, 1984).
2. F. Manibog, "Improved Cooking Stoves in Developing Countries: Problems and Opportunities," *Annual Review of Energy*, Vol. 9, pp. 220–223 (1984).
3. *Ibid.*, pp. 199–228.
4. G. Foley and P. Moss, *Improved Cooking Stoves in Developing Countries* (International Institute for Environment and Development/Earthscan, London, 1985), p. 132.

**Figure 7.5 Energy Use Per Dwelling in Selected OECD Countries, 1970-82**




**Source:** Schipper *et al.*, in press, Reference 13

The potential for further improvements in household energy use is substantial. Overall, average energy use in "all-electric" homes in the United States and Sweden (and probably several other OECD countries) could be reduced by about 80 percent if the most energy-efficient technologies commercially available were introduced to replace the older, less efficient ones (87).

In the *service* sector, which includes commercial and public sector buildings, improvements similar to those in the residential sector have taken place, and further improvements are technically and economically feasible. One survey of informed opinion (experienced architects and engineers) in the United States suggested that a 50 percent reduction in energy use per square meter, on average, was an achievable target for U.S. commercial buildings by the turn of the century (88).

In the *transport* sector, there is further scope for improving the fuel economy of automobiles and light trucks from current levels of about 12–8 liters per 100 kilometers (20–30 miles per gallon) to 4–2.3 liters per 100 km (60–100 m.p.g.), both by increasing engine and drive train efficiency and by reducing vehicle weight and aerodynamic and rolling resistances (89). There has also been a trend toward greater efficiency in air travel, and a 50 percent reduction in the fuel intensity of passenger aircraft, relative to 1977 levels in the United States, appears feasible (90).

*Industrial* energy efficiency trends are more difficult to assess in some ways than those in other sectors because of the greater heterogeneity and complexity of energy use in this sector. As in the other sectors, efficiency improvements may come from good housekeeping measures or new energy conversion systems, but they may also arise from new technological processes for producing a given product (e.g., steel) and from product changes. For example, new processes for producing steel could halve the amount of energy required (91); and similar process innovations are also in prospect for other industries. Two notable examples of more efficient energy conversion technologies are combined heat and power (also known as "cogeneration") systems and electric motors using variable speed drives.

Overall, the scope for cost-effective improvements in energy productivity throughout the economies of the western industrialized countries is very large. The rate at which these improvements are made is largely determined by market forces, particularly fuel prices and the rate of turnover of the capital stock (cars, household appliances, industrial machinery, etc.). The decade following the 1973–74 oil shock was one of exceptionally rapid improvements in energy productivity because of the huge increases in the price of energy. With the prospect of fuel prices declining in real terms, the incentive to introduce some of the efficiency improvements described above may weaken, and their rate of penetration is liable to slacken off. However, energy efficiency improvements can be encouraged by public policy measures, driven by environmental and resource reasons. (See "Energy Projections," below.)

## Structural Trends in the Industrialized Countries

Two basic types of structural change have been taking place in the western industrialized countries that reduce their energy intensity. First, there is the growing importance of services (banking, education, health, etc.) relative to industry, a trend noted for several decades. This phenomenon is reflected in changes in employment patterns and in the fact that the output of the goods-producing sector has not been growing as fast as the GNP.

Second, there has been a decline in some of the most energy-intensive industries in Western Europe and North America, such as iron and steel. This is partly due to the recession and to competition from lower-cost producers in developing countries. But there is also evidence of a longer term shift away from most energy-intensive industries (i.e., those processing basic materials) and toward fabrication and finishing activities, which typically require tenfold less energy per unit of output (92). This shift appears to be due to a combination of factors, including more efficient use of materials in providing essentially the same services, materials substitution, and market saturation. For both traditional materials (steel, cement, and paper) and modern materials (aluminum, ethylene, ammonia, and chlorine) per capita consumption stopped growing in the United States in the 1970s and in most cases began to decline (93). Similar trends have also been observed for the same materials in France, the United Kingdom, and West Germany (94). (See Part IV, Table 8.5.)

## Energy Intensity

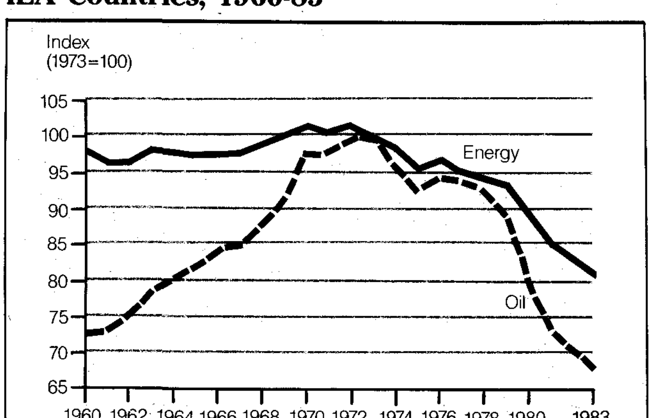
The general trend toward greater energy efficiency and the structural changes noted above have all contributed to an overall change in the relationship between total primary energy consumption and the level of economic activity, i.e., in energy intensity. (See Part IV, Table 8.2.) Saturation in the demand for various energy-intensive services (such as private transport, central heating, and refrigeration) also appears to have reduced energy intensity. This decline for the IEA countries as a whole can be seen in Figure 7.6.

## ENERGY PROJECTIONS

Until the 1973–74 oil shock, and for sometime after, forecasts of energy demand were largely extrapolations of past trends, with some allowance for increases in economic activity and changes in fuel prices. This approach, sometimes known as the "top-down" approach, tended to treat energy demand in a highly aggregated way and assumed that it has a fixed relationship with other variables like fuel prices and GNP. In recent years, however, there has been growing uncertainty about the validity of energy projections formulated in this way. Because the major increases in oil prices (and other energy prices) that occurred in the 1970s were without precedent in recent decades, their longer-term effects on the relationship between energy demand and economic activity are not yet clearly understood (95). In addition, many forecasts during the late 1970s tended to assume historic rates of economic growth and of growth in particular sectors, which proved to be serious overestimates.

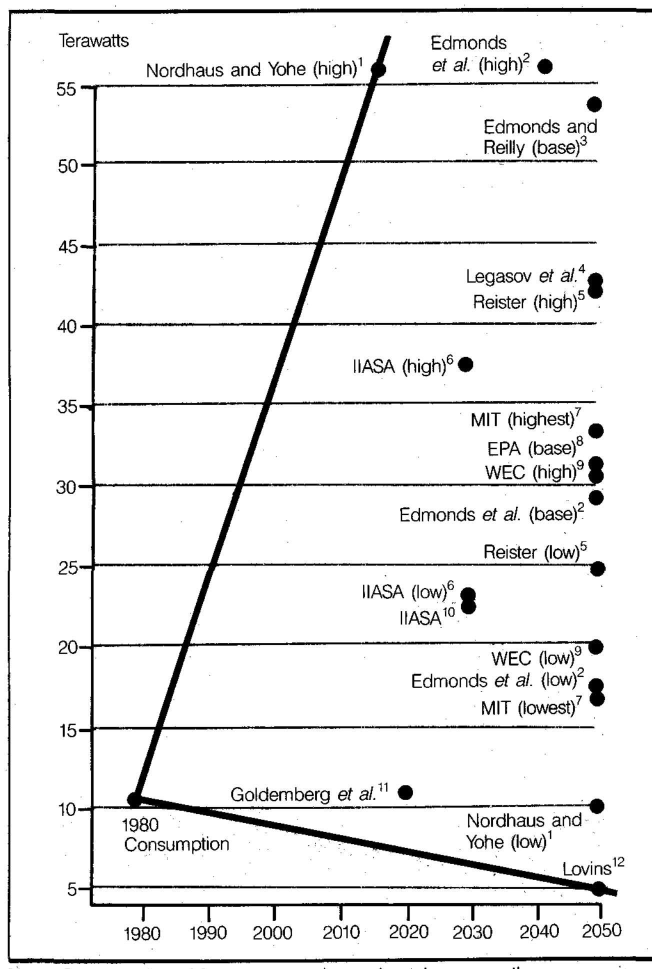
Two important examples of "top-down" projections are those produced by the International Institute of Applied Systems Analysis (IIASA) and those of the World Energy Conference (WEC) (96, 97). (See Figure 7.7.) In both cases there are two projections—high and low demand—based

**Figure 7.6 Energy and Oil Intensities for IEA Countries, 1960-83**




**Source:** International Energy Agency (IEA), 1984, Reference 17.

**Figure 7.7 Comparison of 19 Long-term Projections of Primary Energy Consumption, 1980-2050**




**Note:** Some studies of future energy demand produce more than one projection. The projection that gives the highest or higher level of demand is usually called the "highest" or "high" projection, and the one that gives the lowest or lower level of demand is called the "lowest" or "low" projection. A projection between these two extremes is often called the "base" projection. The fact that the same study may produce a range of projections is related to the fact that varying assumptions are made about the major determinants of energy demand, such as the rate of economic growth and the rate at which energy efficiency improvements occur. (See Table 7.9 and the accompanying text for examples of such variations in assumptions.)

**Sources:**

1. W.D. Nordhaus and G. Yohe, "Future Paths of Energy and Carbon Dioxide Emissions", *Changing Climate* (National Academy of Sciences, Washington D.C., 1983).
2. J.A. Edmonds, *et al.*, *An Analysis of Possible Future Atmospheric Retention of Fossil Fuel $CO_2$*, Report No. DOE/OR/21400-1 (Department of Energy, Washington D.C., 1984).
3. J. Edmonds and J. Reilly, "Global Energy and $CO_2$ to the Year 2050", *Energy Journal*, Vol. 4, No. 3, pp. 21-47 (1983).
4. V.A. Legasov, I.I. Kuz'min, *et al.*, "The Influence of Energetics on Climate", *Fizika Atmospheri i Okeana*, Vol. 11, pp. 1089-1103 (USSR Academy of Sciences, 1984).
5. D.B. Reister, *An Assessment of the Contribution of Gas to the Global Emissions of Carbon Dioxide*, Final Report GRI-84/003 (Gas Research Institute, Chicago, 1984).
6. IIASA, 1981, Reference 96.
7. D.J. Rose, M.M. Miller, *et al.*, *Global Energy Futures and $CO_2$-Induced Climate Change*, MITEL 83-015 (MIT Energy Laboratory, Cambridge, Massachusetts, 1983).
8. S. Seidel and D. Keyes, *Can We Delay a Greenhouse Warming?* Environmental Protection Agency, Washington D.C., 1983).
9. WEC, 1983, Reference 97.
10. H.H. Rogner, Ed., *IIASA '83 Scenario of Energy Development: Summary* (IIASA, Laxenburg, Austria, 1983).
11. Goldemberg *et al.*, 1985, Reference 87.
12. A.B. Lovins, L.H. Lovins, *et al.*, *Least Cost Energy: Solving the $CO_2$ Problem* (Brick House, Andover, Massachusetts, 1981).



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been the single biggest OPEC producer and has acted as the "swing producer," adjusting its output so that other OPEC members could enjoy more stability. During the 1979–81 period, Saudi Arabia increased its production but since then has steadily reduced its output to well below its allotted quota. This decrease, combined with the fact that other OPEC producers have not been keeping to their production quotas, has been creating stresses and strains within the cartel.

Saudi Arabian production peaked in 1980–81 at almost 10 million barrels daily, but then dropped rapidly, reaching 4,690,000 barrels daily in 1984. By August 1985, Saudi Arabian production had slumped to around 2.4 million barrels per day. This fall in output was, of course, paralleled by a fall in revenues: the Saudis' oil revenues in 1984 were $43.7 billion, $70 billion less than three years earlier, and during 1983 and 1984 their foreign exchange reserves fell by 40 percent. Saudi Arabia was running a current account deficit of $20 billion a year—the world's biggest after that of the United States—which threatened to erode its $130 billion of foreign assets.

The situation could not continue, and in the fall of 1985, Saudi Arabia signed contracts with Exxon, Mobil, and Texaco that pegged the price of oil not to OPEC's official price ($28 a barrel of Arabian light crude) but to the value in the marketplace of the refined oil products—gasoline, heating fuel, and diesel—that are derived from crude. In effect, this pricing meant that Saudi Arabia would be selling the oil at about $2.50 less than the official OPEC price. In addition, Saudi Arabia began to expand its output again.

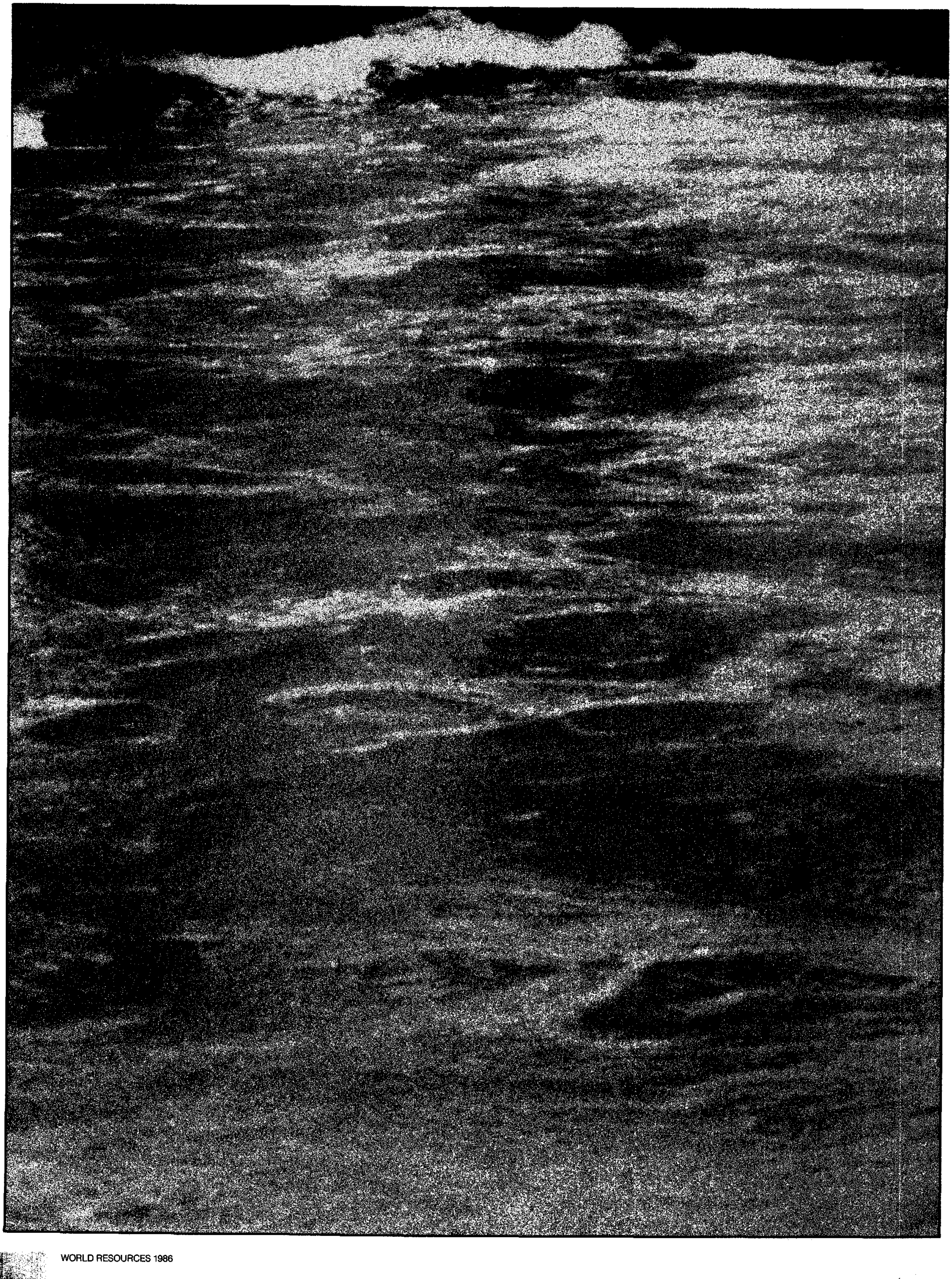
The effect of the Saudis' actions was not felt immediately because the demand for oil increases during the winter and because world inventories of oil were unusually low. It is widely expected, however, that they will start to have a major impact on oil prices later in 1986, leading to further price erosion. A further slackening of demand in Western Europe and an expansion of output by Iraq and Iran are other factors that could cause a drop in prices.

While the level to which oil prices will drop is uncertain, it does seem that the OPEC countries have lost the two pillars of their power—pricing and production controls. OPEC may well return to a position of strength in the 1990s if oil demand picks up again. But for the rest of this decade, it looks as though OPEC will have no more power than any other resource cartel.

## References and Notes


1. Unless otherwise stated, statistics on global, regional, or national energy consumption or production are taken from British Petroleum (BP), *BP Statistical Review of World Energy, June 1984* (BP, London, 1984), pp. 1–32, or the *BP Statistical Review of World Energy, June 1985*, pp. 1–32. The *Statistical Review* does not give data for the Eastern European countries individually or as a group (they are included in the "other centrally planned economies" category); these data were kindly provided by BP's Corporate Planning Department. The statistics for developing countries were derived by adding the statistics in the *BP Statistical Review* for Latin America, Middle East, Africa, Southeast Asia, South Asia, and China and the data for Third World centrally planned economies other than China.
2. World Resources Institute, *Tropical Forests: A Call for Action,* Part I (WRI, Washington, D.C., 1985), p. 5.
3. Food and Agriculture Organization (FAO), *Wood for Energy* (FAO, Rome, 1983), p. 1.
4. Commercial fuels are those bought or sold with money on the market. They constitute the majority of fuels used globally; the quantities used and produced are well quantified because they can be derived from the recorded financial transactions. For this reason, energy statistics (including the British Petroleum data used in this chapter) often cover only commercial fuels but usually exclude commercial biomass fuels statistics. Thus, they give a reasonably accurate picture for developed countries, where non-commercial energy consumption tends to be of only minor importance; however, for developing countries, which often rely heavily on non-commercial fuels, the commercial statistics alone can be very misleading.
5. These per capita figures were derived from the mid-1982 population data from The World Bank, *World Development Report 1984* (The World Bank, Washington, D.C., 1984) for the First and Second World countries, and United Nations Department of International Economic and Social Affairs (UNDIESA) *World Population Prospects* (UNDIESA, New York, 1985) for developing countries, including oil-exporting developing countries.
6. J. Stern, "CMEA Energy Relations in the Mid 1980s," *Regional Review of Eastern Europe and the Soviet Union* (Economist Intelligence Unit, London, 1985), p. 23.
7. The World Bank, *World Development Report 1984* (Oxford University Press, 1984).
8. J. Dunkerley and W. Ramsay, "Energy and the Oil-Importing Developing Countries", *Science*, Vol. 216, p. 590 (1982).
9. *Op. cit.* 1.
10. *Op. cit.* 1.
11. The International Energy Agency (IEA) is an autonomous body within the Organization for Economic Co-operation and Development (OECD). The IEA member countries are the same as those of the OECD except that France, Finland, and Iceland are not members.
12. The following Western industrialized countries are members of the Organization for Economic Co-operation and Development (OECD): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, and West Germany.
13. L. Schipper *et al.*, "Explaining Residential Energy Use by International Bottom-Up Comparisons," *Annual Review of Energy* (in press), p. 1.
14. Organization for Economic Co-operation and Development (OECD), *Energy Balances of OECD Countries 1982/1983* (OECD, Paris, 1985), p. 147, p. 152, and p. 156.
15. L. Schipper and A. Ketoff, *Oil Conservation—Permanent or Reversible? The Example of Homes in the OECD* (Lawrence Berkeley Laboratory, Berkeley, California, 1984), p. 24.
16. *Op. cit.* 13, p. 31.
17. International Energy Agency, *Energy Policies and Programmes of IEA Countries: 1983 Review*, (Organization for Economic Co-operation and Development, Paris, 1984), p. 26.
18. Oil Substitution Task Force, *The Outlook for Oil Substitution: OSTF Report to the 1983 World Energy Congress*, (Graham and Trotnam, London, 1983), p. 8.
19. *Op. cit.* 17, p. 27.
20. *Op. cit.* 1.
21. L. Ivanhoe, "World Crude Output Reserves by Region," *Oil and Gas Journal*, December 24, 1984, pp. 65–68.
22. D. Wilson, *The Demand for Energy in the Soviet Union* (Croom Helm, London and Canberra, 1983), p. 63.
23. *Ibid.*, p. 205.
24. British Petroleum, 1985 (personal communication).
25. G. Leach, 1985 (personal communication).
26. *Op. cit.* 20, p. 65.

27. R. Nehring, "Prospects for Conventional World Oil Resources," *Annual Review of Energy* (Annual Reports Inc., Palo Alto, California, 1982), p. 190.
28. M. King Hubbert, "Measurement of Energy Resources," *Transactions of the American Society of Mechanical Engineers: Journal of Dynamic Systems, Measurement, and Control*, Vol. 101, pp. 16-30, (March 1979).
29. *Op. cit.* 1.
30. *Op. cit.* 1.
31. *Op. cit.* 1.
32. *Op. cit.* 1.
33. *Op. cit.* 14, p. 121.
34. *Op. cit.* 1.
35. *Op. cit.* 1.
36. *Op. cit.* 14, p. 17 and p. 121.
37. J. Stern, *East European Energy and East-West Trade in Energy* (British Institutes, Joint Energy Policy Programme, Policy Studies Institute, Royal Institute of International Affairs, London, 1982).
38. *Op. cit.* 1, p. 2 and p. 20.
39. *Op. cit.* l, p. 20.
40. Gas Energy Review, "World Gas Supply and Demand: 1983–2020," *Gas Energy Review* (Arlington, 1985), Vol. 13, No. 9, p. 7 (1985).
41. U.S. Congress, Office of Technology Assessment, *U.S. National Gas Availability: Gas Supply Through the Year 2000* (U.S. Government Printing Office, Washington, D.C., 1985), pp. 18–19.
42. *Op. cit.* 1.
43. *Op. cit.* 1.
44. *Op. cit.* 1.
45. G. Leach, 1985 (personal communication).
46. The World Bank, *A Survey of the Future Role of Hydroelectric Power in 100 Developing Countries* (World Bank, Washington, D.C., 1984), p. 9.
47. *Op. cit.* 14, p. 5.
48. M. Chadwick and N. Lindman, *Environmental Implications of Expanded Coal Utilization* (Pergamon Press, Oxford, 1982), p. 20.
49. *Op. cit.* 1.
50. *Op. cit.* 1.
51. Office of Technology Assessment (OTA), *Nuclear Power in an Age of Uncertainty* (OTA, Washington, D.C., 1984), pp. 58–59.
52. *Ibid.*, p. 29.
53. *Op. cit.* 1.
54. *Op. cit.* 1.
55. *Op. cit.* 1.
56. *Op. cit.* 46, p. 9.
57. E. Goldsmith and N. Hildyard, *The Social and Environmental Effects of Large Dams* (Wadebridge Ecological Centre, Cornwall, England, 1984), pp. 346.
58. D. Deudney and C. Flavin, *Renewable Energy: The Power to Choose* (Worldwatch Institute, Washington, D.C., 1983), p. 173.
59. *Ibid.*, pp. 171–172.
60. *Op. cit.* 13, p. 45.
61. *Op. cit.* 17, p. 23.
62. For a general overview of biomass fuels in the Third World, see *Biomass Energy Systems: Building Blocks for Sustainable Agriculture* (World Resources Institute, Washington, D.C., 1985).
63. Food and Agriculture Organization (FAO), *1983 Yearbook of Forest Products* (FAO, Rome, 1985), p. 78.
64. Food and Agriculture Organization (FAO), *State of Food and Agriculture 1984 (CL 86/2)* (FAO, Rome, 1984), p. 25.
65. J. Dunkerley and W. Ramsay, *Analysis of Energy Prospects and Problems of Developing Countries* (Resources for the Future, Washington, D.C., 1983).
66. *Op. cit.* 2.
67. Food and Agriculture Organization (FAO), *Fuelwood Supplies in Developing Countries* (FAO, Rome, 1983), pp. 16–17.
68. *Ibid.*
69. J. Jones and A. Otarola, *Diagnostico Socio-Economico sobre el Consumo y Produccion de Lena en Fincas Pequenas de Nicaragua* (CATIE, Costa Rica, 1981).
70. P. Fleuret and A. Fleuret, "Fuelwood Use in a Peasant Community: A Tanzanian Case Study," *Journal of Developing Areas*, Vol. 12, No. 3, (1978).
71. F. Bonnet-Madin *et al.*, *La Consommation de Bois de Feu en Zone Rurale, Etude de Six Villages du Niger et du Mali* (Association Bois de Feu, Marseille, 1983).
72. B. Samanta *et al.*, *Social Forestry in Orissa: Case Study on Fuel Availability and its Impact on Women's Time Disposition and Lifestyle* (Operations Research Group, Bhubanwar, India, 1982).
73. Social Forestry Monitoring Advisory Board, Social Forestry Project in Tamil Nadu, *Report on Preliminary Surveys (Second Round)* (SFMAB, Institute of Development Studies, Madras, 1982).
74. For data on Sri Lanka and Kenya, G. Leach *et al.*, *Energy and Development: A Comparison of 13 Countries* (International Institute for Environment and Development, London; and ATW Research, Regensburg, 1985); and for data on Tanzania, P. O'Keefe and B. Munslow, *Energy and Development in Southern Africa: SADCC Country Studies, Part II* (The Beijer Institute, Stockholm, 1984).
75. G. Barnard and L. Kristoferson, *Agricultural Residues as Fuel in the Third World* (International Institute for Environment and Development/Earthscan, London, 1985), p. 12.
76. *Op. cit.* 67, p. 11.
77. *Op. cit.* 67, p. 117 and p. 118.
78. M. Bhagavan, "The Woodfuel Crisis in the SADCC Countries," *Ambio*, Vol 13, No. 1, p. 25 (1984).
79. G. Barnard, 1985 (personal communication).
80. *Op. cit.* 78, p. 14.
81. F. Manibog, "Improved Cooking Stoves in Developing Countries: Problems and Opportunities," *Annual Review of Energy*, Vol. 9, p. 221 (1984).
82. *Op. cit.* 75, p. 54.
83. For a discussion of successful tree-planting schemes, see *Tropical Forests: A Call for Action* (World Resources Institute/The World Bank/United Nations Development Program, Washington, D.C., 1985).
84. *Op. cit.* 81, p. 203.
85. G. Foley and P. Moss, *Improved Cooking Stoves in Developing Countries* (International Institute for Environment and Development/Earthscan, London, 1985).
86. G. Foley and G. Barnard, *Farm and Community Forestry* (International Institute for Environment and Development/Earthscan, London, 1984).
87. J. Goldemberg *et al.*, "An End-Use Oriented Global Energy Strategy," *Annual Review of Energy*, Vol. 10, p. 649 (1985).
88. Solar Energy Research Institute, *A New Prosperity: Building a Sustainable Energy Future* (Brick House, Andover, Massachussets, 1981).
89. *Op. cit.* 87, pp. 650–651.
90. F. Von Hippel, *US Transportation Energy Demand* (Center for Energy and Environmental Studies, Princeton, New Jersey, 1981).
91. *Op. cit.* 87, p. 654.
92. M. Ross *et al.*, *Energy Demand and Materials Flows in the Economy* (Center for Energy and Environmental Studies, Princeton, New Jersey, 1985), pp. 1–8.
93. E. Larson *et al*, *Material Consumption Patterns and Industrial Energy Demand in Industrialized Countries* (Center for Energy and Environmental Studies, Princeton, New Jersey, 1984), p. 70.
94. *Op. cit.* 92, p. 36.
95. *Op. cit.* 17, p. 25.
96. International Institute of Applied Systems Analysis, Energy Systems Program Group, *Energy in a Finite World—A Global Systems Analysis* (Ballinger, Cambridge, Massachusetts, 1981).
97. World Energy Conference, *Energy 2000–2020: World Prospects and Regional Stresses* (Graham and Trotman, London, 1983).
98. *Op. cit.* 87, p. 623.
99. *Op. cit.* 87, p. 622.
100. *Op. cit.* 1.
101. *Op. cit.* 1.



# 8. Freshwater

Above all else, solar energy and water maintain the life-support systems on earth. Out of a total water volume of approximately 1.4 billion cubic kilometers ($km^3$), more than 97 percent is ocean water, unsuitable for human use. Of the 3 percent of the earth's water that is fresh, an estimated 77.2 percent of this is in "cold storage," frozen in ice caps and glaciers. Most of the remaining supplies of freshwater—22.4 percent—is groundwater and soil moisture. This leaves only a very small amount of surface freshwater—0.35 percent contained in lakes and swamps and less than 0.01 percent in rivers and streams (1). Table 8.1 shows these amounts as "water compartments." Obviously, freshwater is a limited resource: there is only so much of it circulating throughout the planet's ecosystems.

Ancient Romans had access to roughly the same amount of water as the modern Romans do. The critical difference is population: in 100 AD Rome had a population of 1 million, while today it is closer to 4 million (2). Clearly, burgeoning populations not only need increasing supplies of freshwater for an expanding array of uses, but societies must learn to use existing resources more efficiently.

## CONDITIONS AND TRENDS

### FRESHWATER AS A FINITE RESOURCE

In general, water availability is tied to the global hydrological cycle (3). (See Figure 8.1.) Every year approximately 453,000 cubic kilometers ($km^3$) of water are evaporated from the surface of the world's oceans (1 cubic kilometer equals 1 billion cubic meters or 1 trillion liters). Of this tremendous amount, roughly 90 percent returns to the oceans as precipitation, while the remaining 10 percent (about 41,000 $km^3$) is transported by the prevailing winds over the continents. Here it combines with slightly more than 72,000 $km^3$ of evaporated water from the land masses to provide a gross continental precipitation of about 113,000 $km^3$. It is this "flow" of water—enough to cover the land surface of the earth to a depth of 83 centimeters—that sustains natural and human ecosystems on an annual basis. A larger portion of it goes to recharge soil moisture and groundwater flows. The rest, both surface and shallow sub-surface water—some 41,000 $km^3$—eventually gathers in rivers and is returned to the sea to complete the cycle (4). An equilibrium is maintained between the inflow as air moisture to the continents, and the outflow from the rivers and groundwater aquifers to the sea.

Table 8.2 shows the world's average annual water balances by major regions (5). It is the amount of stable runoff in any given area that determines how much water is actually available for human use on a year-round basis. Mark L'vovich, of the Institute of Geography, USSR Academy of Sciences, defines stable runoff as the "base flow" from groundwater into rivers plus stable "surface runoff" added by water storage in lakes and reservoirs.

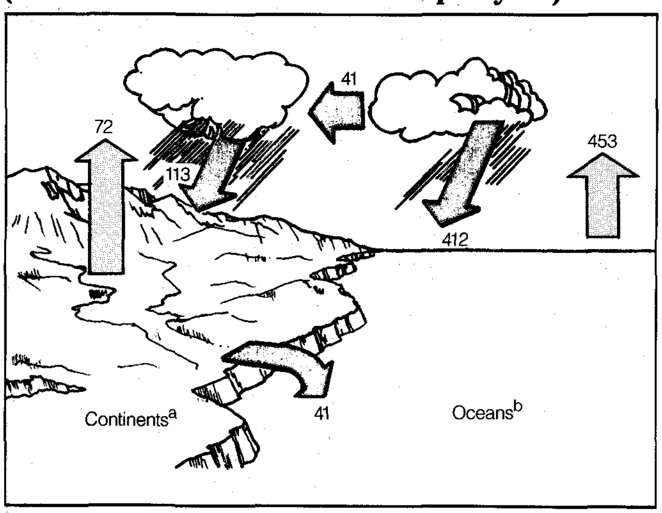
**Table 8.1 The Earth's Water Compartments: Estimated Volume of Water in Storage and Average Residence Time in the Earth's Environments**

| Environmental Parameter | Volume (km³) | Average Residence Time |
|---|---|---|
| Atmospheric Water | 113,000 | 8 to 10 days |
| Oceans and Open Seas | 1,370,000,000 | 4,000+ years |
| Freshwater Lakes and Reservoirs | 125,000 | From days to years |
| Saline Lakes and Inland Seas | 104,000 | — |
| River Channels | 1,700 | 2 weeks |
| Swamps and Marshes | 3,600 | Years |
| Biological Water (used by plants) | 65,000 | 1 week |
| Moisture in Soil and Unsaturated Zone (zone of aeration) | 65,000 | 2 weeks to 1 year |
| Groundwater | 4,000,000 to 60,000,000 | From days to tens of thousands of years |
| Frozen Water (glaciers and ice caps) | 30,000,000 | Ten to thousands of years |

**Sources:**
1. R.L. Nace, Ed., *Scientific Framework of World Water Balance*, Technical Papers in Hydrology No. 7, Table 2 (UNESCO, Paris, 1971).
2. R.L. Nace, *Water of the World* (U.S. Government Printing Office, Washington, D.C., 1980).

The hydrological cycle does not spread water around in an equitable manner; it is unevenly distributed around the globe even within relatively small countries. In a general sense, the world is divided into water surplus and water deficit regions. Figure 8.2 sketches in these regions, which are categorized according to water availability as seen from a vegetation perspective. Water is in surplus when precipitation is large enough to satisfy the demands of the vegetation cover. When precipitation is lower than this potential demand, there is a water deficit. By this yardstick, most of Africa (except for a small section of tropical West Africa), much of the Middle East, the western United States and northwestern Mexico, parts of Chile and Argentina, and all of Australia (except for a thin slice of eastern coastline) are areas of severe water deficits, where evapotranspiration exceeds annual precipitation.

**Figure 8.1 Global Circulation of Water (thousands of cubic kilometers per year)**




**Notes:**
a. 29 percent of earth's surface.
b. 71 percent of earth's surface.
**Source:** M. Falkenmark, "Do We Need Hydrological Research?", in Swedish, *Forskning och Framsteg*, No. 5, 1974.

The natural unit of the hydrological cycle is the river basin, or any drainage area forming a segment of that basin. A water divide separates basins or sub-basins from each other. All precipitation falling within the water divide that does not evaporate or leave by a deep aquifer is drained by a stream or river. Where the hydrographic pattern produces small river basins, there may be many of them within a particular country, such as Sweden, whereas large river basins like the Rhine, whose watershed extends over 220,000 square kilometers, may encompass a half dozen countries (the Rhine drains parts of Austria, Switzerland, France, West Germany, Liechtenstein, and Holland). The amount of water available to any particular country is supplied in two ways: through the inflow of exogenous water from upstream countries—which is essentially controlled by those countries—and from endogenous water provided by the precipitation falling over a country's territory (6).

The precipitation pattern, particularly its seasonality, is reflected in river flow. During the year, the flow fluctuates between dry season flow (low flow) and wet season flow (flood flow). The dry season flow forms the dependable part of the water supply, whereas the rapidly passing flood water is available only during part of the year. If this water is stored in reservoirs, it increases the dependable flow of water (stable runoff) available for societal uses.

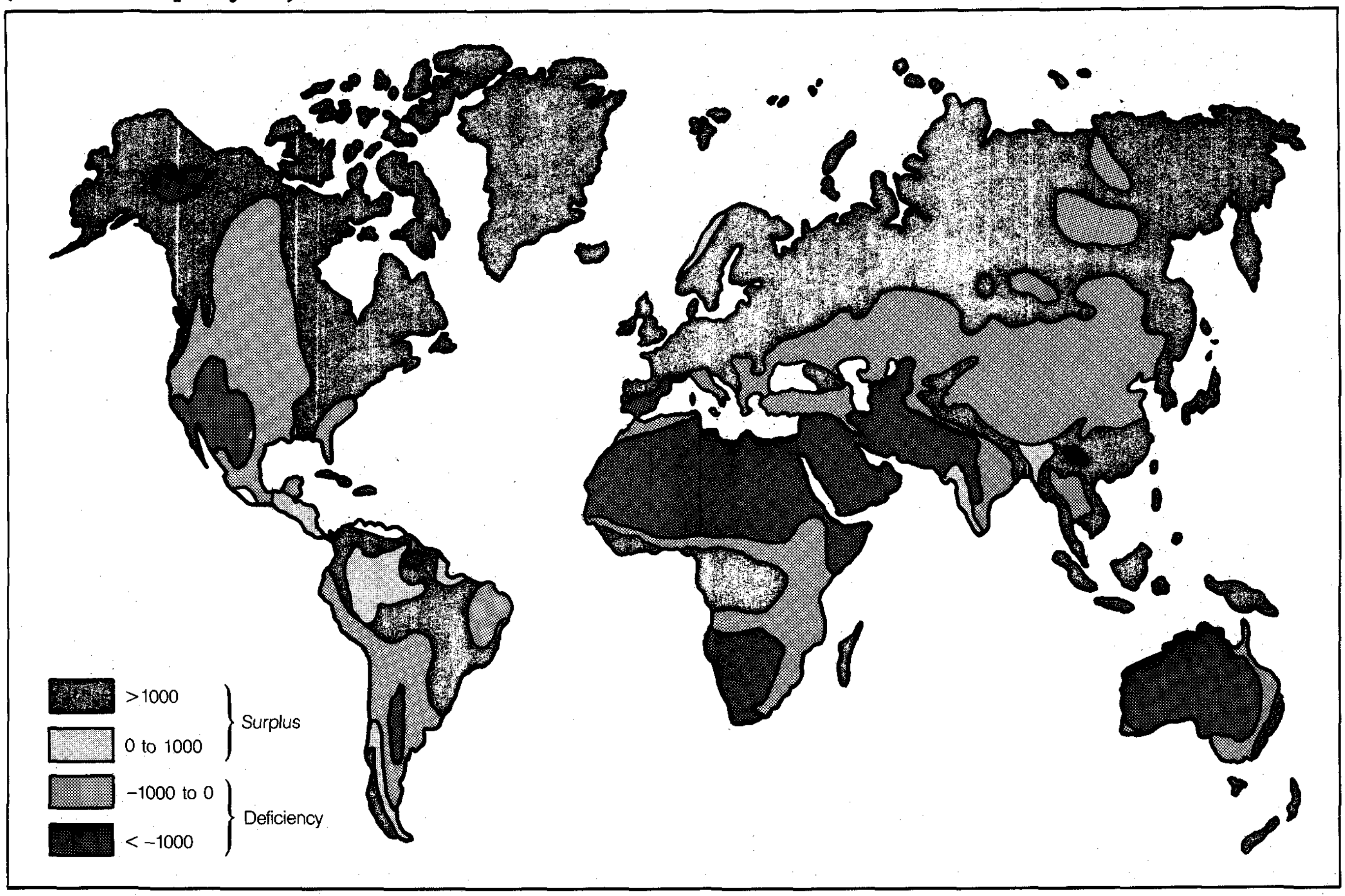
The relative amount of water available for use in any given area is limited not only by the water cycle, in particular the stable runoff, but also by the size of the population: the larger the population, the more people there are competing for water resources. In some cases

**Table 8.2 Average Annual Water Balances of the World: A Comparison of Three Estimates**

| Region | Volume of Water (thousands of cubic kilometers) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Baumgartner[a] 1975 | | | USSR Monograph[b] 1974 | | | L'vovich[c] 1974 | | |
| | P[d] | E[d] | R[d] | P | E | R | P | E | R |
| Europe | 6.6 | 3.8 | 2.8 | 8.3 | 5.3 | 3.0 | 7.2 | 4.1 | 3.1 |
| Asia | 30.7 | 18.5 | 12.2 | 32.3 | 18.1 | 14.1 | 32.7 | 19.5 | 13.2 |
| Africa | 20.7 | 17.3 | 3.4 | 22.3 | 17.7 | 4.6 | 20.8 | 16.6 | 4.2 |
| Australia | 7.1 | 4.7 | 2.4 | 7.1 | 4.6 | 2.5 | 6.4 | 4.4 | 2.0 |
| North America | 15.6 | 9.7 | 5.9 | 18.3 | 10.1 | 8.2 | 13.9 | 7.9 | 6.0 |
| South America | 28.0 | 16.9 | 11.1 | 28.4 | 16.2 | 12.2 | 29.4 | 19.0 | 10.4 |
| Antarctica | 2.4 | 0.4 | 2.0 | 2.3 | 0 | 2.3 | X | X | X |
| Land Areas[e] | 111 | 71 | 40 | 119 | 72 | 47 | 113 | 72 | 41 |
| Oceans | 385 | 425 | –40 | 458 | 505 | –47 | 412 | 453 | –41 |
| **World** | **496** | **496** | **0** | **577** | **577** | **0** | **525** | **525** | **0** |
| | Depth of Water (continent-wide average) (millimeters) | | | | | | | | |
| Europe | 657 | 375 | 282 | 790 | 507 | 283 | 734 | 415 | 319 |
| Asia | 696 | 420 | 276 | 740 | 416 | 324 | 726 | 433 | 293 |
| Africa | 696 | 582 | 114 | 740 | 587 | 153 | 686 | 547 | 139 |
| Australia | 803 | 534 | 269 | 791 | 511 | 280 | 736 | 510 | 226 |
| North America | 645 | 403 | 242 | 756 | 418 | 338 | 670 | 383 | 287 |
| South America | 1,564 | 946 | 618 | 1,595 | 910 | 685 | 1,648 | 1,065 | 583 |
| Antarctica | 169 | 28 | 141 | 165 | 0 | 165 | X | X | X |
| **World** | **973** | **973** | **0** | **1,130** | **1,130** | **0** | **1,030** | **1,030** | **0** |

X = Not available
**Notes:**
a. A. Baumgartner and E. Reichel, *The World Water Balance* (Elsevier, Amsterdam, 1975).
b. USSR, National Committee for IHD, *World Water Balance and Water Resources of the Earth* (Leningrad, 1974).
c. L'vovich, *Global Water Resources and the Future* (Moscow, 1974).
d. P=Precipitation; E=Evaporation; R=Runoff.
e. Values are adjusted upward to include Antarctica for comparison with corresponding volumes derived by the other two authors.
**Source:** U.N. Water Conference, 1978, Reference 5.

**Figure 8.2 Global Water Surplus and Deficiency[a] (millimeters per year)**




**Note:** a. Defined as difference between annual precipitation and evapotranspiration. Evapotranspiration corresponds to the water demand from a potential crop not suffering from water deficiency.
**Source:** Falkenmark, 1977, Reference 3.

increased and competing demands have reached critical levels, especially in countries such as Israel, Egypt, Kenya, and even Poland (which is not an arid country). Table 8.3 shows total and per capita water availability for some selected countries (7). Large tropical nations like Brazil and large temperate countries like Canada have an abundance of freshwater: some 38,280 cubic meters ($m^3$) per person per year and 122,000 $m^3$/person/year, respectively, while large dry countries like Egypt have only 1,200 $m^3$ per person, most of it from the Nile River. Although the data show that the 13 countries listed as "Water-Rich" have no real problems with total water availability, it tells nothing about the distribution of freshwater within these countries, or its quality and utility for human use. Thirteen countries have been placed on the list of "Water-Poor countries." It should be noted that most of sub-Saharan Africa and the Middle East have chronic water shortages, as do parts of large countries like the United States, Australia, and the Soviet Union.

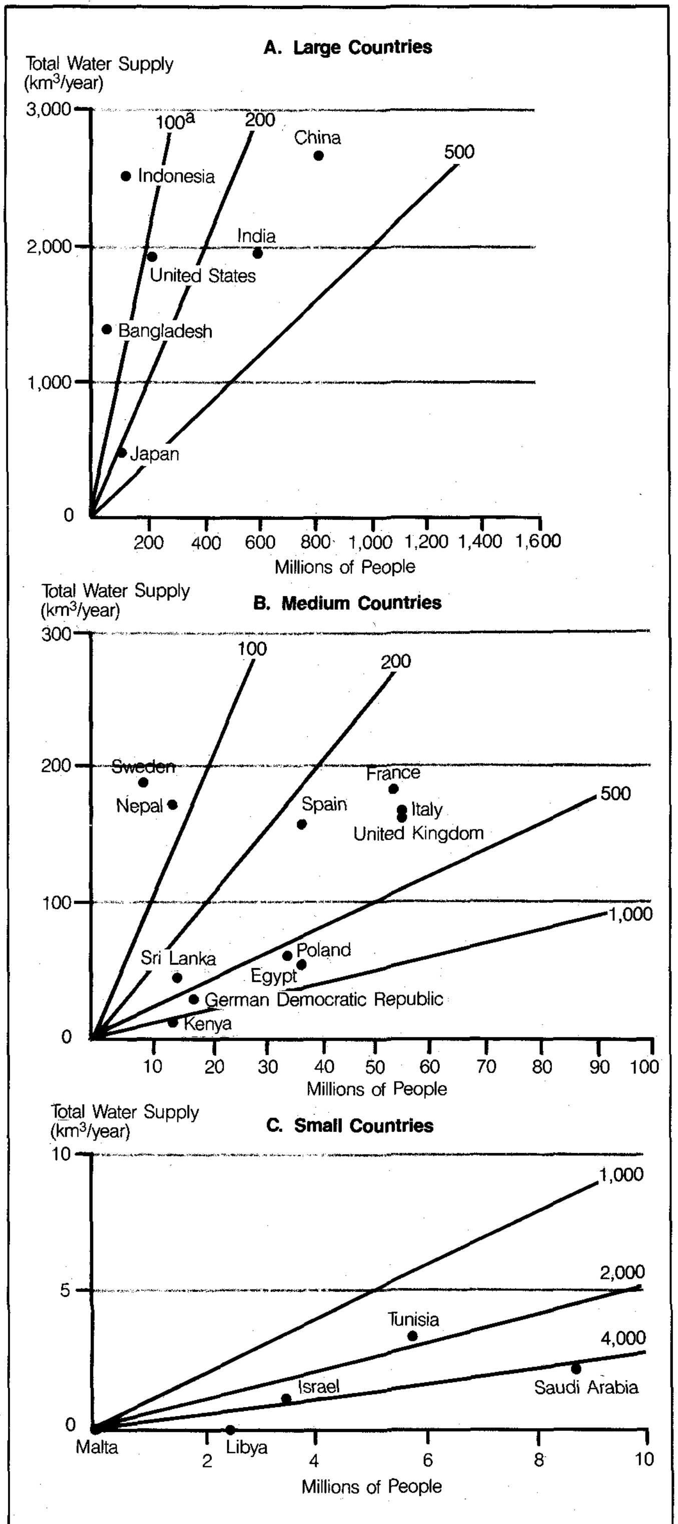
Figures 8.3A, B, and C show another way to look at the problem of population size and water availability. In water-short countries like Tunisia and Saudi Arabia, 2,000 and 4,000 people, respectively, compete for every 1 million cubic meters of water on a yearly basis. In relatively

**Table 8.3 Total and Per Capita Water Availability in Selected Countries, 1985**

| | Total ($km^3$/yr) | Per Capita (thousand cubic meters per year) |
|---|---|---|
| **Water-Rich Countries** | | |
| 1 Canada | 3,122 | 121.93 |
| 2 Panama | 144 | 66.06 |
| 3 Nicaragua | 175 | 53.48 |
| 4 Brazil | 5,190 | 38.28 |
| 5 Ecuador | 314 | 33.48 |
| 6 Malaysia | 456 | 29.32 |
| 7 Sweden | 183 | 22.11 |
| 8 Cameroon | 208 | 21.41 |
| 9 Finland | 104 | 21.33 |
| 10 USSR | 4,714 | 16.93 |
| 11 Indonesia | 2,530 | 15.34 |
| 12 Austria | 90 | 12.02 |
| 13 United States | 2,478 | 10.43 |
| **Water-Poor Countries** | | |
| 1 Malta | 0.025 | 0.07 |
| 2 Libya | 0.700 | 0.19 |
| 3 Barbados | 0.053 | 0.20 |
| 4 Oman | 0.660 | 0.54 |
| 5 Kenya | 14.800 | 0.72 |
| 6 Egypt | 56.000 | 1.20 |
| 7 Belgium | 12.500 | 1.27 |
| 8 South Africa | 50.000 | 1.54 |
| 9 Poland | 58.800 | 1.57 |
| 10 Haiti | 11.000 | 1.67 |
| 11 Peru | 40.000 | 2.03 |
| 12 India | 1,850 | 2.43 |
| 13 China | 2,680 | 2.52 |

**Source:** Forkasiewicz and Margat, 1980, Reference 7.

**Figure 8.3 Global Comparison of Water Competition in Three Groups of Countries**




**Note:** a. Numbers at ends of lines represent the numbers of people competing for 1 million cubic meters of water per year.
**Source:** Falkenmark, in press, 1986, Reference 9, based on data from Reference 7.

water-abundant countries like France, Italy, and England, only about 350 people are competing for the same amount (8). Some experts contend that once the number of individuals depending on one flow unit (i.e. 1 million cubic meters of water per year) increases above 2,000, the country is likely to suffer from inherent water deficit problems (9).

Figure 8.4 compares the water-short region of Africa with that of the western United States (10). The shaded areas show where the annual precipitation minus evapotranspiration is between 0 and 10 millimeters a year. The African belt of water-short countries corresponds fairly accurately with the "hunger belt" that cuts a wide swath through sub-Saharan Africa, extending into southern Africa. (See Box 8.1.) Although both regions suffer from chronic water deficits, the western United States compensates for this by utilizing groundwater resources and employing vast water basin transfer schemes, thereby making desert land productive.

## Variability of Rainfall

Figure 8.5 depicts the areas of the world with the highest interannual variability of rainfall. North and sub-Saharan Africa, the Arabian peninsula, southern Iran, Pakistan, and western India mark the largest contiguous region with the highest variability of rainfall—more than 40 percent—over the long-term average. This high percentage is also the norm for the southwestern United States and northwestern Mexico, southwest Africa, the very eastern tip of Brazil, and parts of Chile. In these regions the amount of rainfall every year is highly unpredictable (11).

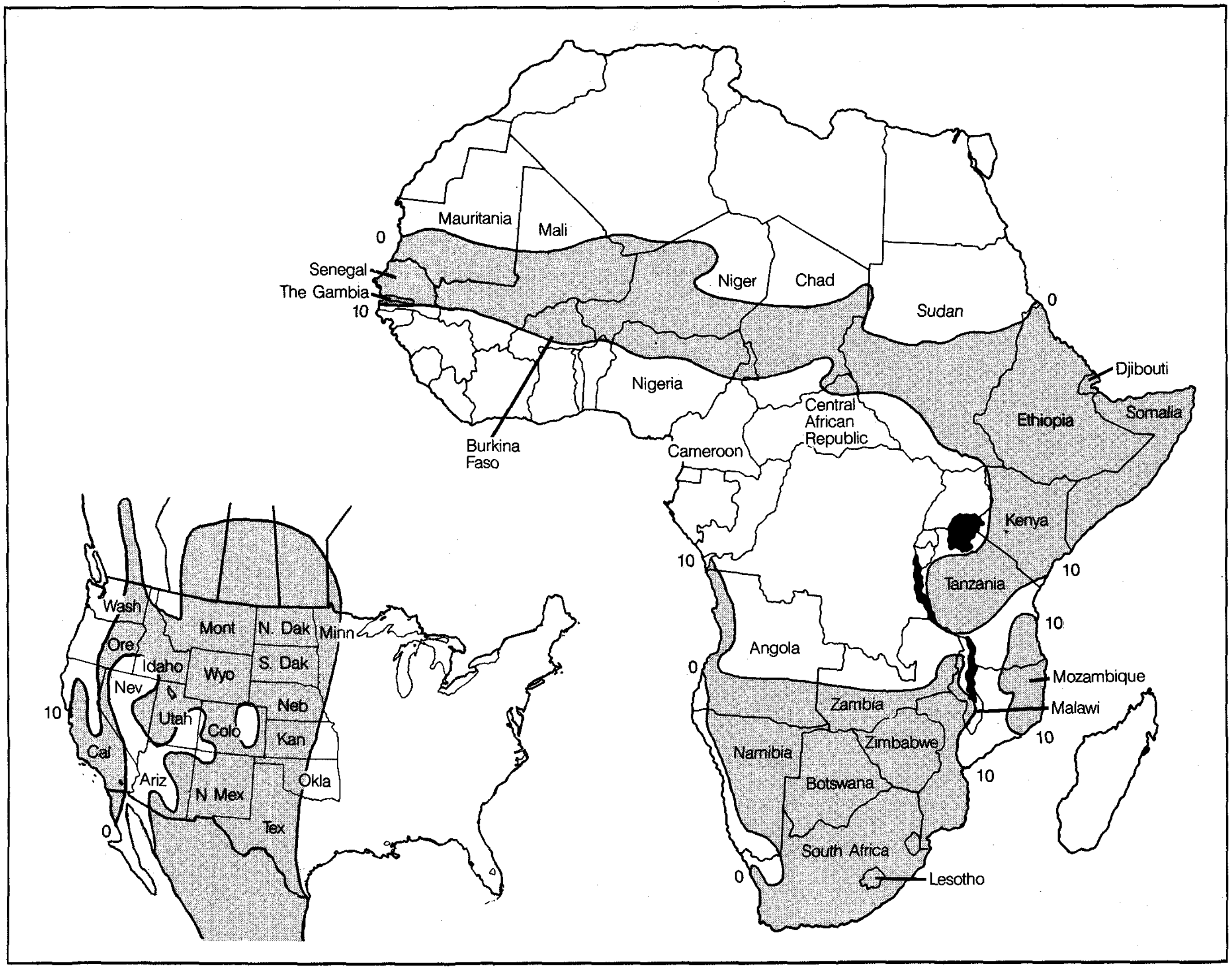
In the Sahel, not only is much of the rainfall "unreliable," but there is less of it today than 50 or even 30 years ago. Recent data indicate that there has been a significant downward trend in the actual amount of rain falling over much of Sahelian Africa (12). At one measuring station in Mali, for example, the mean amount of rainfall during a 50-year period from 1934–83 was 715 millimeters (mm), while during the last 15 years (from 1968–83) the mean amount of precipitation was only 577 mm a year (12). The same is true for measuring sites in Senegal, Burkina Faso, and Niger. (See Table 8.4.) Such cycles of drought have always been a common feature of this region.

In other parts of Africa the picture is not much different. In East Africa (Kenya, Tanzania, Uganda, Rwanda, and Burundi), rainfall also varies significantly from year to year. It is not unusual for a rainy season to be delayed or not appear at all. In fact, the highest annual total rainfall in any single year in the region can be "as much as four times the lowest recorded total" (13).

## Stable Runoff

Some 41,000 cubic kilometers ($km^3$) of water flow off the land every year into the sea, but only the stable part of this runoff—some 9,000 $km^3$—can be economically

**Figure 8.4** **Areas of Africa and North America with Poor Water Availability**




**Note:** In the shaded areas, precipitation minus evapotranspiration is between 0 and 10 millimeters per year.
**Source:** Baumgartner and Reichel, 1975, Reference 10.

tapped for human use (14). The tropical regions of Latin America and Asia have the largest amounts of total runoff. Asia seems to have the biggest share, ranging from 12,200 $km^3$ to 14,100 $km^3$ (15). (See Table 8.2.) However, when measured by the average depth of runoff, Latin America leads with up to 685 mm a year compared with Asia's highest estimate of 324 mm. This is not unusual, given the fact that Latin America's average annual precipitation is 1,500 mm, 50 percent greater than the world average of 970 mm (16).

The volume of runoff in Africa, Australia, Europe, and North America combined is less than 40 percent of the total (17).

Of the nearly 41,000 cubic kilometers of net annual input into the continents, the stable runoff amounts to only about 13,000 $km^3$. However, since about 5,000 $km^3$ flows through sparsely populated regions, like the Amazon Basin, the total volume readily available for human use is whittled down to about 9,000 $km^3$ per year (18), of which the Soviet Union alone has 1,300 $km^3$ (19).

Although there appears to be no scarcity of water when viewed from the gross aggregate amount available—if water use doubles over the next 20 years, as some predict, and nothing is done to increase access to stable runoff or reduce demand through conservation measures—water scarcities could develop even in "Water-Rich" regions. The total runoff also disguises glaring regional differences. For example, Africa's runoff per unit of land area is about one-fifth that of South America's (20). This situation is due largely to the lower amounts of precipitation that characterize Africa. However, if stable runoff is viewed solely from the point of view of per cap-

## Box 8.1 The African Drought — An Object Lesson in Fundamental Land/Water Interdependencies

The widespread "hunger crisis" that has ravaged sub-Saharan Africa since 1983–84 was scarcely unpredicted—scientists had been sounding alarm bells for years that an ecological disaster was going to strike Africa. It was predictable that the famine developed precisely in the zone where large-scale land degradation has been increasing in intensity and extent over the past decade (See Figure 8.4, main text). In this region, where precipitation minus evapotranspiration equals only 0–10 millimeters a year, groundwater recharge is extremely irregular, rendering water supplies in wells sensitive to even short periods of drought (1).

### ZONE OF RECURRENT WATER SHORTAGES

Large parts of tropical and subtropical Africa are arid or semi-arid. Often the monthly rainfall is barely enough to support plant cover. Much of the continent suffers from a devastating interannual variability of rainfall (2). (See Figure 8.5, main text.) Typically, the variability is on the order of 30–40 percent for sub-Saharan Africa (3). This means that drought is part of the typical climatic picture. Evidently, agriculture in semi-arid Africa is somewhat like a water "lottery" (4). Crop success depends to a large extent on the capacity of local populations to manage the risks involved. And the risks are formidable. As Table 1 shows for Mali, in the 100 millimeter (mm) rainfall zone, there is never as much as four months of pasture, in dry years perhaps only one or two months. Even in the 600 mm zone, there is a risk of crop failure during dry years (5).

The importance of rainfall variability has been repeatedly stressed by scientists in the past decade. However, the habit ingrained in "northern" scientists to talk about "normal precipitation" in the South is seriously misleading when applied to dry areas like Africa, where "normal" has a completely different meaning. Multi-year, recurrent droughts are normal for this region—in fact there have already been three of them during this century (6). And the last 15-year period has been characterized by a persistent rainfall deficit, when compared to the long-term average. The "wet" 1960s have been followed by nearly two decades of relatively dry years.

### FROM DROUGHTS TO DISASTERS

The Sahelian region is a classic case of human mismanagement of the environment. Traditional "risk management" in this drought-prone area used to be a largely nomadic way of life. People and their animals moved south during the dry season in order to find adequate pasture. In the 1960s, countries in the Sahelian region were given foreign aid and loans from international development agencies to launch many well-drilling projects in the belief that social development would benefit from access to water year-round. In the wake of the wells, the presence of easily accessible water encouraged a sedentary way of life and in some cases, where there was sufficient pasture, the traditional southward migration was abandoned. This change, in turn, resulted in the rapid deterioration of pasturelands around the wells.

**Table 1 Fluctuating Length of Growing Season in Southern and Central Mali**

| Station | Long-Term Annual Rainfall mm/yr | Length of Growing Season: Normal (Dry) Years (99 years of 100) Pasture | Normal (Dry) Years Crop | Extremely Wet Years (1 year out of 100) Pasture | Extremely Wet Years Crop |
|---|---|---|---|---|---|
| Bougouni | circa 1200 | 190 | 150 | 250 | 210 |
| Niono | circa 600 | 110 | 70 | 220 | 170 |
| Kidal | circa 100 | 30 | 10 | 100 | 50 |

**Source:** Diawara, 1984, Reference 5.

Today, the drought-prone areas of the Sahel are occupied by both sedentary farmers and nomadic pastoralists, and during dry years, overgrazing is a serious problem throughout the entire region. The potential biomass production of the area, which determines the carrying capacity of the land, and therefore places limits on the size of the human and animal populations that can be sustained, has often been surpassed. A German scientist based in Mali for 26 years has described the land degradation process, using three examples (7). In Central Gourma in east Mali, the "desertification" of large tracts of once arable land was accelerated ironically by the installation of water wells. Although a vigorous pasture rotation policy was implemented, initially to control the risk of overgrazing, the system soon collapsed and the wells are now used year-round. As a result, the desert has moved 350 kilometers south over the past 20 years. In central Niger, a vast area nearly the size of West Germany has been seriously degraded due to a similar process. Water wells were drilled, which altered the migration patterns, placing increasing stress on the carrying capacity of this fragile water-short region. The situation was aggravated by the rainfall deficiencies of the last 15 years. Similar conditions exist over wide areas in Senegal and southwest Mauritania, where the "well euphoria" of the 1960s has caused disasters, best described by a frequently used expression in the Sahelian countries: "Where there is plenty of water, there is no grass; where there is plenty of grass, there is no water" (8).

### DISASTER RELIEF STRATEGIES COLLAPSING

Even if droughts are a naturally recurrent pheonomena in all countries with a dry season climate (both semi-arid and semi-humid), they tend to develop into disasters in areas with high population densities, although sparsely populated regions with degraded carrying capacities are also severely affected (i.e., parts of Mali and Chad). In such areas, dry years reduce the amount of food available to subsistence farmers to a bare minimum, even if there is water in the wells.

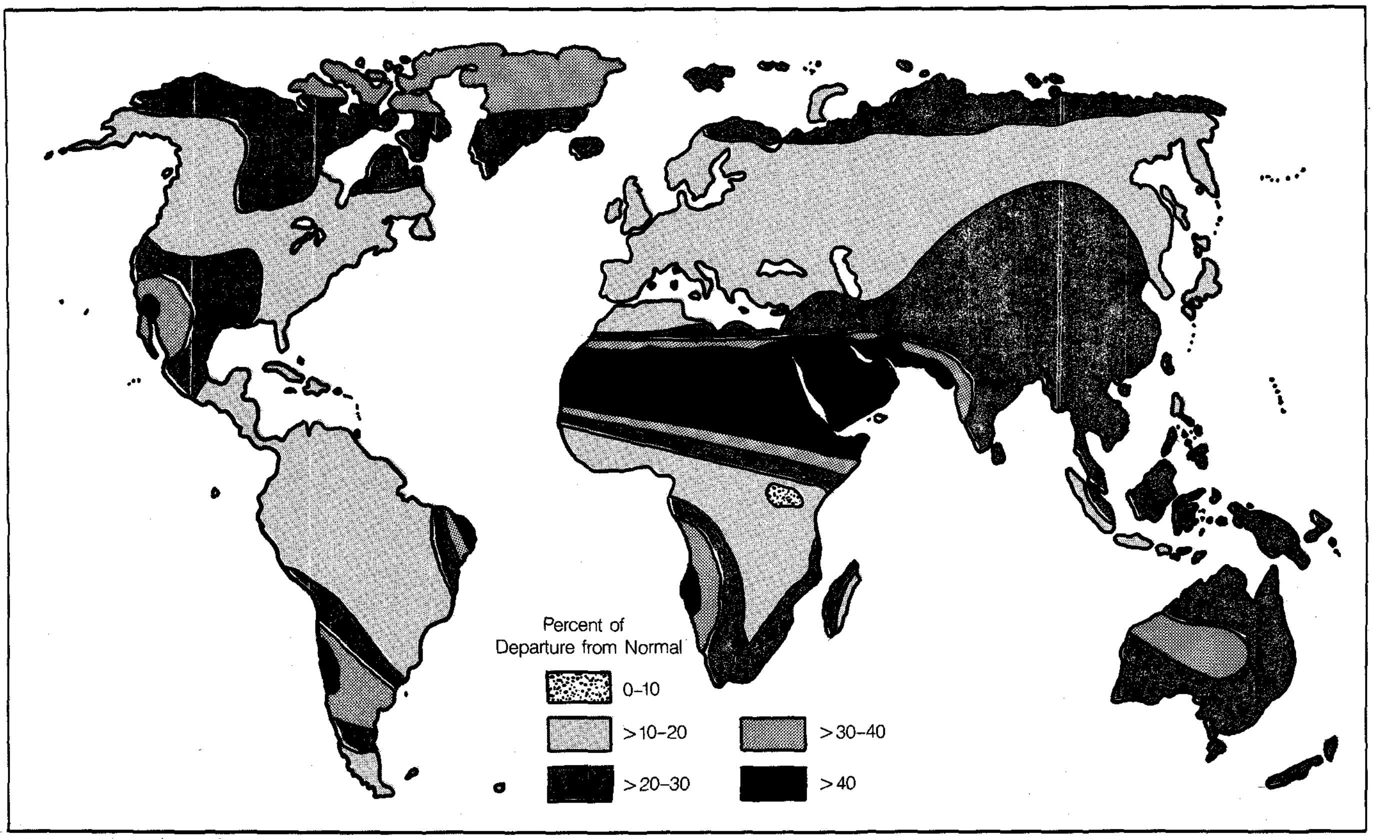
An analysis of such "natural" disasters, carried out by the Swedish Red Cross, shows that they are triggered by a chain process, rather than one event (9). Widespread drought forces people off the land and into relief centers or refugee camps. Massive population concentrations in the camps soon foster chronic shortages of food and water.

Traditionally, disaster relief took the form of emergency assistance, directed largely toward reducing human suffering and hunger. The general philosophy of relief was to aid the stricken populations momentarily, until "normal" conditions returned. In other words, it was a question of helping the victims back to a viable *status quo*. The present continuing crisis in sub-Saharan Africa has highlighted the fact that there is no longer a "normal" condition to return to; overpopulation and short-sighted land use policies have combined to make the disaster a continuing one.

### References and Notes

1. M. Falkenmark, "Macro-Scale Water Supply/Demand Comparison on the Global Scene—A Hydrological Approach," in *Hydrology and Earth Sciences*, R. Keller, Ed. (Beitrage zur Hydrologie, 1986, in press); and A. Baumgartner and E. Reichel, *The World Water Balance* (Elsevier, Amsterdam, 1975).
2. Y. Gustafsson, "Variations in Rainfall as a Natural Constraint on Agriculture," *AMBIO*, Vol. 6, No. 1, p. 34 (1977); and A.K. Biswas, "Climate and Development," in *Climate and Development*, Vol. 13, A.K. Biswas, Ed. (Tycooly International Publishing Ltd., Dublin, 1984).
3. A.K. Biswas, "Climate and Water Resources," in *Climate and Development*, Vol. 13, A.K. Biswas, Ed. (Tycooly International Publishing Ltd., Dublin, 1984).
4. M. Falkenmark, "Macro-Scale Water Supply/Demand Comparison on the Global Scene—A Hydrological Approach," in *Hydrology and Earth Sciences*, R. Keller, Ed. (Beitrage zur Hydrologie, 1986, in press).
5. A. Diawara, *A Rainfall Generator and Water Balance Model for Mali* (Royal Institute of Technology, Stockholm, Bulletin No. TRITA-VBI-121, 1984).
6. J. Sircoulon, "Les Données Hydropluviometriques de la Sêcheresse Récente en Afrique Intertropicale. Comparison avec les Sêcheresses 1913 et 1940," *Cahiers de e' O.R.S.T.O.M. serie Hydrologie*, Vol. 13, No. 2 (1976).
7. R. Reichelt, *Die Desertifikation Sudlich der Sahara, Ursachen und Folgen* (Manuscript CILSS, Ouagadougou, Burkina Faso, 1984).
8. *Ibid.*
9. Swedish Red Cross, *Prevention Better than Cure, Report on Human and Environmental Disasters in the Third World* (Swedish Red Cross, Stockholm and Geneva, 1984).

**Figure 8.5** Interannual Variability of Rainfall




**Source:** Biswas, 1984, Reference 11.

ita availability, then Asia has only one half of the world's average gross water availability, while Africa is almost exactly at the world average of 8,562 cubic meters per person per year (21).

In order to compensate for increasing demands on limited water resources, many countries—especially those in "Water-Poor" regions—are trying to capture a larger share of the gross runoff. By the end of 1978, for example, the Peoples Republic of China had constructed some 84,000 reservoirs with a total storage capacity of 400 billion cubic meters (22).

The Soviet Union has also increased its accessible stable runoff by building dams and reservoirs so that its total now stands at 16,930 cubic meters per person per year (23).

One crucial element in securing future water supplies is the ability of countries, especially those in water-scarce areas, to increase their access to stable runoff by building dams and reservoirs, tapping groundwater reserves, and learning to use existing reserves in a more sustainable fashion.

### Groundwater: The Resource

The amount of water stored in the ground is enormous—between 4 and 60 million cubic kilometers—exceeding the amounts in rivers, lakes, reservoirs, swamps, marshes, and the atmosphere combined. (See Table 8.1.) However, if water above 4,000 meters depth is included, this estimate narrows to between 8 and 10 million $km^3$ (24). But only a very small portion of this water is economically exploitable. So despite the great quantities of groundwater available, relatively little of it has actually been tapped. Part of the problem is that in much of the Third World, the extent and quality of groundwater supplies are unknown and so too are the costs and types of technology needed to extract it. In Central America, for example, the most abundant amounts of groundwater are thought to be in Nicaragua and Costa Rica, although both Guatemala and El Salvador have significant reserves in their Pacific coastal lowlands (25). Nevertheless, very few systematic data on the region's aquifers are available. The same is true for South America, Africa, and large parts of Asia.

Recent trends suggest that groundwater will be increasingly exploited during the next 20 years, especially in North America, unless pumping costs escalate to the point where it becomes uneconomical to tap groundwater reserves. (See "Emerging Trends in Water Use," below.)

## WATER USE DRIVES HUMAN ACTIVITIES

Water use is another area saddled with rather poor statistics, even in countries with otherwise good statistical data bases. When industrial and agricultural demand for water increases, pressures build on limited resources. As can be seen in Figure 8.6A, total global water use has increased rapidly since about 1950, while per capita water use has

**Table 8.4 Mean Annual Rainfall in the Sahel**
*(millimeters)*

| | | Mean Amount From Reference Sources | | | Mean Amounts During the Last: | | | | Last 30 Years As Percentage of the Reference Sources | Last 16 Years As Percentage of the Reference Sources |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Station | WMO[a] | Wernstedt[b] | Lebedev[c] | 50 years (1934-83) | 40 years (1944-83) | 30 years (1954-83) | 15 years (1968-83) | | |
| Senegal | St. Louis | 347 | 390 | 389 | 313 | 296 | 281 | 233 | 72-81 | 60-67 |
| | Podor | X | 311 | 309 | 285 | 276 | 258 | 200 | 83 | 64-65 |
| | Matam | X | 527 | 520 | 462 | 431 | 411 | 314 | 78-79 | 60 |
| | Linguere | 535 | 533 | 531 | 462 | 449 | 418 | 358 | 78-79 | 67 |
| | Dakar | 578 | 599 | 578 | 500 | 481 | 458 | 329 | 76-79 | 55-57 |
| | Diourbel | X | 650 | 660 | 628 | 619 | 589 | 482 | 89-91 | 73-74 |
| | Kaolack | X | 823 | 830 | X | X | 655 | 535 | 79-80 | 64 |
| | Tambachounda | 942 | 886 | 880 | 879 | 839 | 826 | 709 | 88-94 | 75-81 |
| | Kedougou | X | 1,307 | 1,307 | 1,238 | 1,226 | 1,239 | 1,147 | 95 | 88 |
| | Kolda | X | 1,215 | 1,217 | X | X | 1,126 | 963 | 93 | 79 |
| | Ziguinchor | 1,547 | 1,559 | 1,553 | X | X | 1,347 | 1,133 | 86-87 | 73 |
| Mali | Kayes | 821 | 750 | 748 | 715 | 708 | 657 | 577 | 80-88 | 70-77 |
| | Nioro | 631 | 709 | 707 | 548 | 544 | 518 | 412 | 73-82 | 58-65 |
| | Mopti | 552 | 540 | 541 | 511 | 512 | 495 | 458 | 90-92 | 83-85 |
| | Hombori | 454 | 390 | 410 | 402 | 409 | 390 | 353 | 86-100 | 78-91 |
| | Gao | 261 | 271 | 271 | 235 | 236 | 225 | 200 | 83-86 | 74-77 |
| | Menaka | 263 | 249 | 251 | 256 | 260 | 250 | 202 | 95-100 | 77-81 |
| | Tomboctou | 225 | 201 | 208 | X | X | X | 147 | X | 65-73 |
| | San | 743 | 749 | 746 | 738 | 741 | 737 | 683 | 98-99 | 91-92 |
| | Segou | 724 | 702 | 706 | 688 | 679 | 680 | 590 | 94-97 | 81-84 |
| | Bamako | 1,099 | 1,075 | 1,000 | 983 | 964 | 949 | 869 | 86-95 | 79-87 |
| | Kita | 1,151 | 1,116 | 1,116 | X | X | X | 882 | X | 77-79 |
| | Kenieba | 1,408 | 1,353 | 1,287 | X | 1,248 | 1,228 | 1,083 | 87-95 | 77-84 |
| | Bougouni | 1,337 | 1,311 | 1,316 | 1,246 | 1,193 | 1,186 | 1,082 | 89-90 | 81-83 |
| | Koutiala | 1,022 | 982 | 982 | 989 | 996 | 963 | 859 | 94-98 | 84-87 |
| | Sikasso | 1,329 | 1,373 | 1,376 | 1,221 | 1,210 | 1,189 | 1,144 | 86-89 | 83-86 |
| Burkina Faso | Dori | 542 | 483 | 501 | X | X | 533 | 456 | 98-110 | 84-94 |
| | Ouahigouya | 715 | 728 | 706 | 686 | 664 | 641 | 572 | 88-91 | 79-81 |
| | Dedougou | X | 975 | 991 | 893 | 872 | 846 | 738 | 85-87 | 74-76 |
| | Ouagadougou | 879 | 881 | 879 | 835 | 837 | 846 | 796 | 96 | 90-91 |
| | Fada N'Gourma | 890 | 890 | 834 | 878 | 899 | 911 | 824 | 102-109 | 93-99 |
| | Boromo | 1,029 | 1,079 | 1,029 | 951 | 938 | 911 | 889 | 84-89 | 82-86 |
| | Bobo Dioulasso | 1,185 | 1,181 | 1,134 | 1,116 | 1,130 | 1,095 | 1,028 | 92-97 | 87-91 |
| | Gaoua | 1,161 | 1,162 | 1,247 | 1,103 | 1,059 | 1,062 | 1,036 | 85-91 | 83-89 |
| Niger | Tahoua | 407 | 385 | 385 | 394 | 404 | 396 | 336 | 97-103 | 83-87 |
| | Tillabery | 510 | 500 | 500 | X | X | X | 376 | X | 74-75 |
| | Niamey Aero | 636 | 594 | 582 | 575 | 576 | 570 | 516 | 90-98 | 81-89 |
| | Birni N'Konni | 597 | 602 | 601 | X | X | 517 | 464 | 86-87 | 77-78 |
| | Maradi | 642 | 622 | 623 | 565 | 561 | 539 | 454 | 84-87 | 71-73 |
| | Zinder | 549 | 530 | 515 | 486 | 479 | 460 | 401 | 84-89 | 73-78 |
| | Magaria | X | 617 | 616 | X | 599 | 587 | 500 | 95 | 81 |
| | Maine Soroa | 404 | 412 | 418 | X | X | 374 | 324 | 89-93 | 78-80 |
| | N'Guigmi | 236 | 213 | 212 | 222 | 229 | 228 | 192 | 97-108 | 81-91 |
| | Gaya | X | 861 | 852 | X | 828 | 818 | 803 | 96 | 94 |

X = not available
**Notes:**
a. World Meteorological Organization (WMO), *Climatological Normals (CLINO) for Climate and Climate Ship Stations for the Period 1931-1960* (WMO, Geneva, 1971).
b. F.L. Wernstedt, *World Climatic Data* (Climatic Data Press, Lemont, Pennsylvania, 1972).
c. A.N. Lebedev, Ed., *The Climate of Africa, Part I: Gidrometeoizdat In Russian* (Leningrad, 1968).
**Source:** Todorov, 1985, Reference 12.

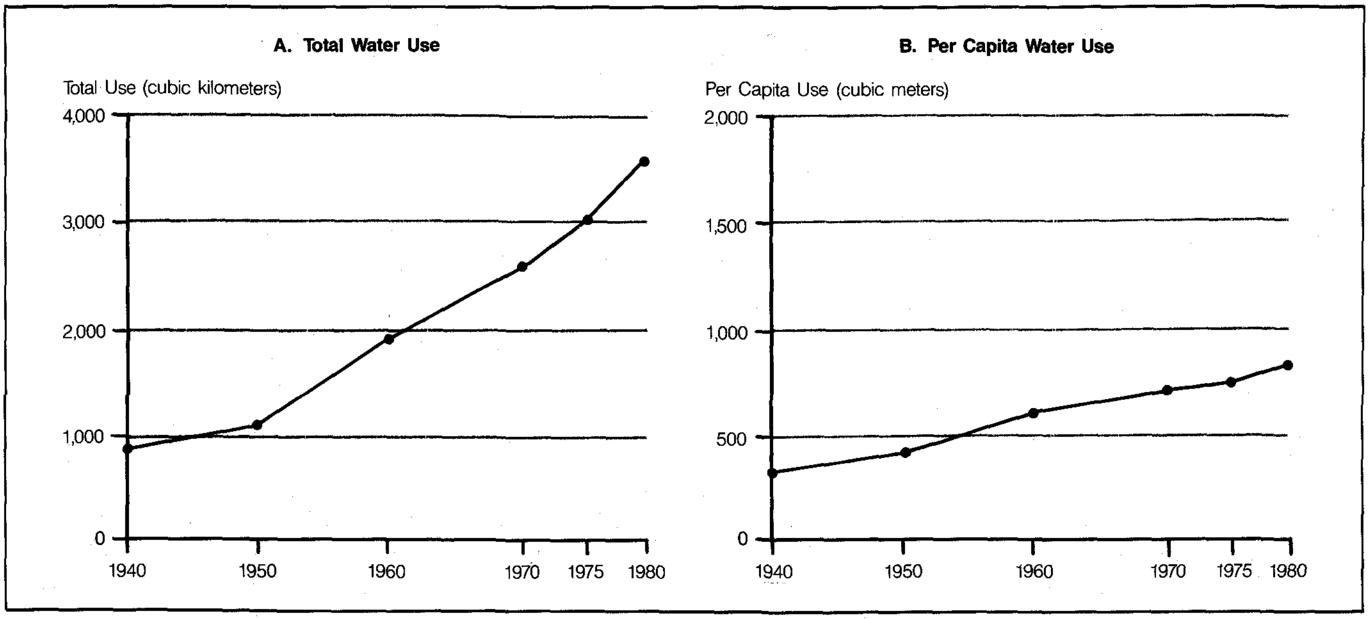
steadily risen over the same period. (See Figure 8.6B.) Table 8.5 shows the estimated water use in selected countries, distinguishing among public (municipal), industrial, electric cooling, and agricultural withdrawals. As expected, the United States leads in water withdrawals with 472 cubic kilometers withdrawn every year (1.6 trillion liters per day, or 7,200 liters per person per day). The largest share of this water (49 percent) serves industry and electricity-generating plants (nuclear and fossil-fueled). Compare these figures to data for India, which withdraws 380 cubic kilometers per year, or a little more than 1 trillion liters per day, but because of the large population, this impressive figure amounts to only 1,500 liters per person per day, with 93 percent of it withdrawn for irrigation (26).

According to the United Nations Environment Program (UNEP), global water use breaks down into three broad categories (estimated in rough annual percentages): irrigation (73 percent), industry (21 percent), and public uses (6 percent) (27). Water use patterns differ significantly from North to South. In the developed countries, industries account for 40 percent or more of all water use (in Eastern Europe industries can guzzle up to 80 percent), while in the Third World, the overwhelming bulk of water goes for irrigation, with industry seldom accounting for even 10 percent (28). These trends are likely to continue into the next century.

It should be noted that Asia and North America (United States and Canada) withdraw about the same amount of water for public and household purposes (both urban and rural), but considering North America's population of 263 million compared with Asia's total of 2.6 billion, its per capita use of public water supplies is much higher than Asia's. North America uses the greatest total amount of water for industrial purposes (29), while Asia leads all continents in the use of water for irrigation.

Increasing water withdrawals for municipal, industrial, and agricultural purposes, shown as a ratio of freshwater renewal, indicate the extent to which some areas, particularly North and sub-Saharan Africa and the Middle East, were already coming close to their limits a decade ago (1975) (30). (See Figure 8.7.) Today, some 256 million peo-

**Figure 8.6** Total and Per Capita Global Water Use, 1940–80




**Sources:**
1. Falkenmark, 1977, Reference 3.
2. Postel, 1985, Reference 26.

ple live in regions where 50–100 percent of the stable runoff is used.

## Public Water: Drinking Water and Sanitation

Most public uses (31) of water fall within the categories of drinking water, household water, and water for sanitation and sewage systems (although most statistics include commercial use in this category as well). Overall, only a small percentage of total water withdrawals—some 5–6 percent globally—is used for public (municipal) purposes, but the quality of this water is very important (32). The World Health Organization (WHO) estimated in 1980, that three out of five people in developing countries did not have easy access to safe drinking water and three out of four persons in these countries had no kind of sanitary facility—not even a pit or bucket latrine (33). As many as 1.8 billion people are exposed to diseases by drinking contaminated (non-potable) water (34). Every day throughout the world some 25,000 people die from a combination of factors related mostly to using contaminated water; four out of five deaths of children in developing countries are due to water-related diseases (35).

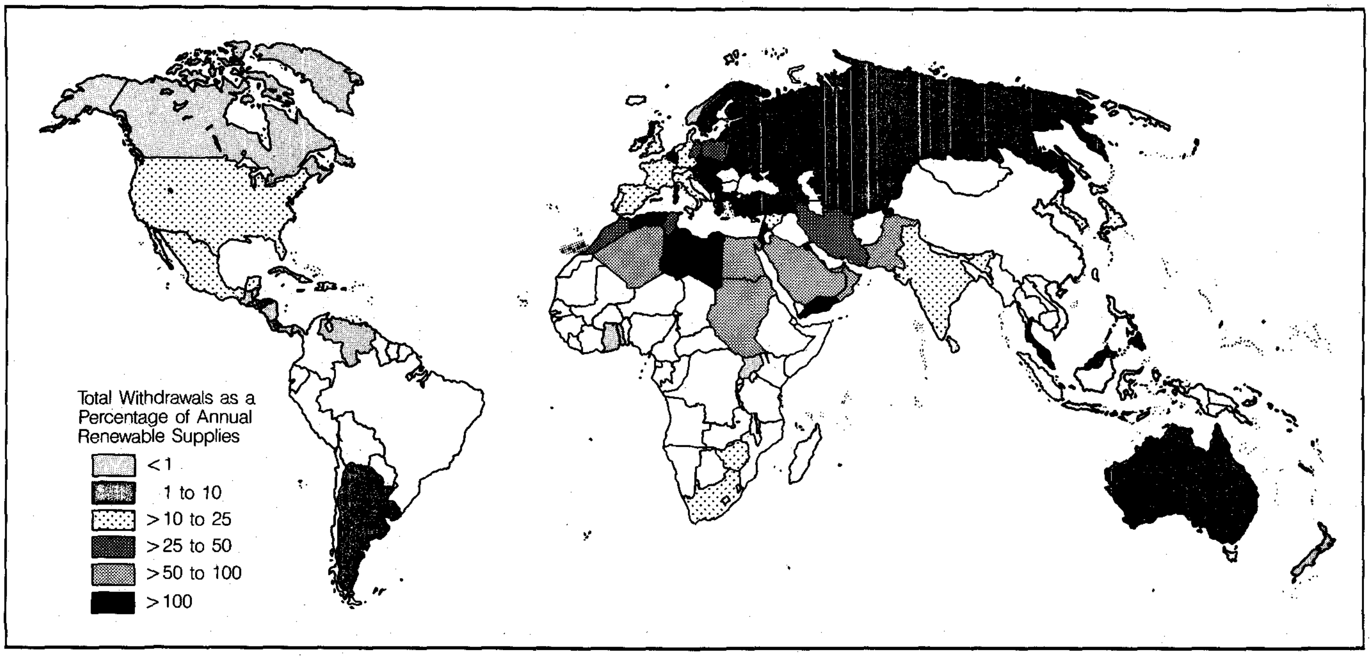
According to WHO, 71 percent of the urban dwellers in 55 selected Third World countries had access to clean drinking water in 1980, as opposed to only 32 percent of the rural populations in 61 developing countries (36). In those same countries a wide gulf also separates urban and rural populations when it comes to having access to sanitation facilities: 41 percent of the urban population was served by some form of sanitation facility, as opposed to 12 percent of the rural population (37).

**Table 8.5** Average Annual Water Use in Selected Countries, Total and Per Capita

| | Water Withdrawal | | Share Withdrawn by Sector (percent) | | | |
|---|---|---|---|---|---|---|
| Country | Total (km³) | Per Capita (m³) | Public | Industry | Electric Cooling | Agriculture/Irrigation |
| United States | 472.000 | 1,986 | 10 | 11 | 38 | 41 |
| Canada | 30.000 | 1,172 | 13 | 39 | 39 | 10 |
| Egypt | 45.000 | 962 | 1 | 0 | 0 | 98 |
| Finland | 4.610 | 946 | 7 | 85 | 0 | 8 |
| Belgium | 8.260 | 836 | 6 | 37 | 47 | 10 |
| USSR | 226.000 | 812 | 8 | 15 | 14 | 63 |
| Panama | 1.300 | 596 | 12 | 11 | 0 | 77 |
| India | 380.000 | 499 | 3 | 1 | 3 | 93 |
| China | 460.000 | 460 | 6 | 7 | 0 | 87 |
| Poland | 15.900 | 423 | 14 | 21 | 40 | 25 |
| Libya[p] | 1.470 | 408 | 17 | 0 | 0 | 83 |
| Oman | 0.043 | 350 | 2 | 0 | 0 | 98 |
| South Africa[p] | 9.200 | 284 | 17 | 0 | 0 | 83 |
| Nicaragua[i] | 0.890 | 272 | 18 | 45 | 0 | 37 |
| Barbados | 0.027 | 102 | 45 | 35 | 0 | 20 |
| Malta | 0.023 | 60 | 100 | 0 | 0 | 0 |

**Notes:**
p = Public and Industry
i = Industry and Electric Cooling
**Sources:**
1. For all data except China: Forkasiewicz and Margat, 1980, Reference 7.
2. For data on China: V. Smil, *The Bad Earth: Environmental Degradation in China* (Zed Press, London, 1984).

**Figure 8.7 Index of Freshwater Use, 1975**




**Source:** Forkasiewicz and Margat, 1980, Reference 7.

In order to meet the International Drinking Water Supply and Sanitation Decade targets for clean water and sanitation by 1990, an additional 768 million rural residents in the Third World would have to be served with water supplies, and 322 million with sanitation facilities (38).

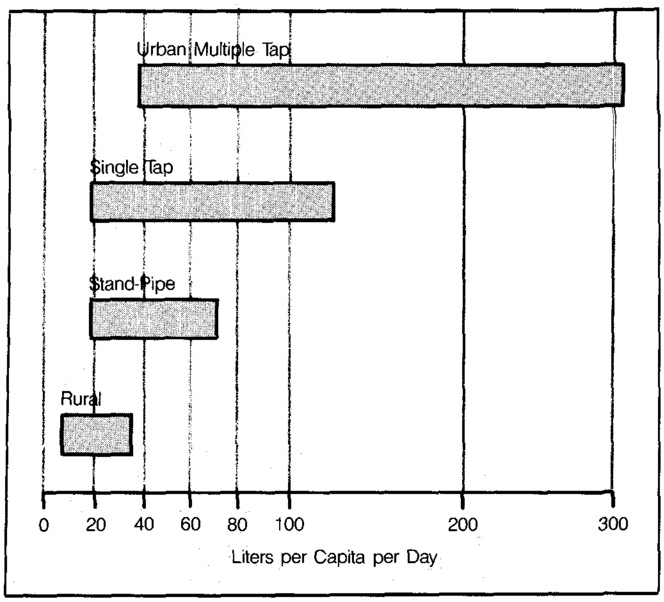
Figure 8.8 demonstrates how the amount of water used depends on the mode of distribution, income levels, and geographical location (39). Multiple urban taps result in a withdrawal of between 40 and 350 liters per person per day, while rural distribution in the Third World—water is usually hand-carried by women and children—ranges from near the biological minimum of 2–5 liters per person per day up to 40 liters, and the quality of the water varies considerably. Water-related diseases tend to occur when the availability of clean water falls below 50 liters per person per day. It should be noted that urban dwellers in most of the Third World have improved access to clean drinking water as compared to their rural counterparts. It has been estimated that more than 90 million rural residents of Latin America alone have little or no access to safe supplies of potable water (40). Similarly, 23,000 villages in India had no access to clean drinking water, as of 1982 (41).

A similar picture is seen throughout Africa: in rural Tanzania, for instance, only 28 percent of the people have access to safe drinking water, as opposed to 82 percent in the capital of Dar-es-Salaam (42). WHO data for 1980 show that in Kenya only 21 percent of the rural population was served with safe drinking water, while 39 percent of rural residents had access to sanitation facilities. For Madagascar the percentages were 9 percent and unknown, respectively, and for Angola 12 percent and 15 percent, respectively (43). The same pattern prevails over much of the rest of Africa.

## Industry

In industry, water is used for cooling, processing, boiling, and transporting, in addition to air conditioning and cleaning. There is a great diversity among various types of industry in terms of both the amounts of water needed and its efficient use. A few industries, principally primary metals, chemical products, petroleum refining, pulp and paper, and food processing, account for a full

**Figure 8.8 World Daily Household Water Use Per Capita, 1976**




**Source:** U.N. Water Conference, 1978, Reference 5, p. 48.

two thirds or more of all industrial water withdrawals (44). The specific industrial processes used heavily influence the amount of water needed. An "inefficient" plant may use up to 20 times more water than an "efficient" one in manufacturing the same product (45).

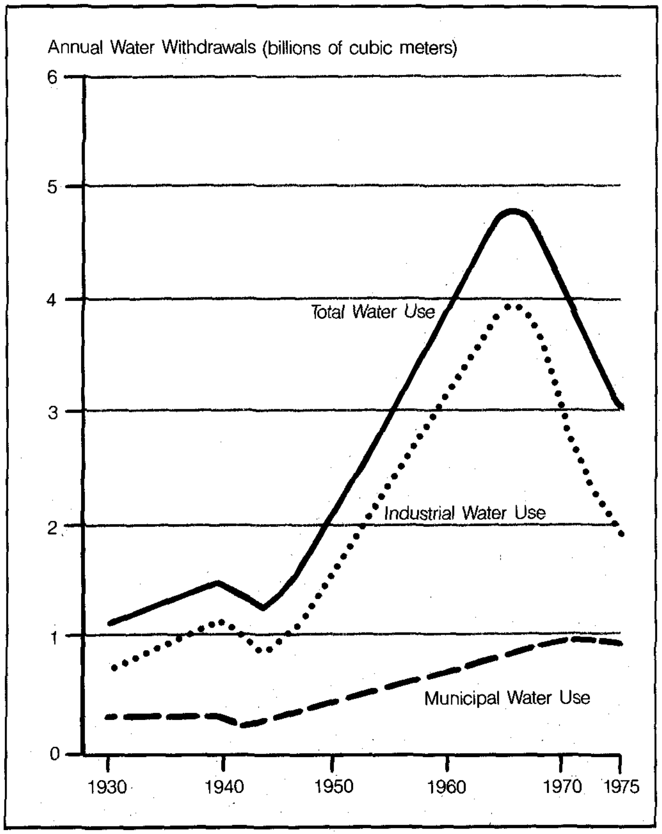
In a general sense, the heaviest industrial water users mentioned above have improved their water use efficiencies significantly over the past decade. In Japan, for example, total industrial water use increased from 50 million cubic meters in 1965 to 120 million cubic meters in 1974, but by the mid-1970s, two thirds of it was recycled water compared with one third in 1965 (46).

By 1975, U.S. industry as a whole had achieved a water recycling rate of 2.2. This means that water brought into the plant was used on average 2.2 times before it was discharged. And about 90.5 percent of the original water withdrawn was returned to the surface water system (47). West Germany has a similar recycling rate (2.0), as does Japan (1.5). Given the trend to recycle process water, some researchers have predicted that the industrial demand for water in the United States will actually decline from the current level of more than 1,500 liters per capita per day to less than 1,000 liters per capita per day by the year 2000 (48).

Some advanced industrial countries in Europe have also begun to decrease their industrial raw water demand. Swedish industries, for instance, were forced by water quality laws to re-circulate their process water, resulting in a rapid decline in industrial water demand (49). (See Figure 8.9.)

In the Third World, on the other hand, the trend is just the opposite; industrial water demands are increasing as countries struggle to expand their industrial base.

**Figure 8.9 Municipal, Industrial, and Total Water Withdrawals in Sweden, 1930–75**




**Source:** Falkenmark, 1977, Reference 49.

## FOCUS ON: IRRIGATION

Agriculture, mainly irrigation, accounts for the largest single share of global water use—some 73 percent (50). Although estimates vary widely (as do definitions of irrigated land), one recent reckoning puts the total world irrigated area at 271 million hectares with most of the recent increase in the European part of the Soviet Union, Asia, and South America (51). (See Table 8.6.) India has seen the most rapid growth. In the 1960s, the gross area under irrigation expanded from about 28 million hectares to 37 million hectares and today it stands at around 50 million hectares (52). (See also Chapter 4, "Food and Agriculture," Table 4.5.)

Despite the extensive use of irrigation to increase crop yields, especially in Asia, irrigation efficiencies are rather low. Farmers tend to over-irrigate because of low prices and cheap gravity systems, so it is not uncommon that 70–80 percent of the water withdrawn from a river for irrigation purposes never reaches its intended destination. Even in the Colorado River Basin in the southwestern United States, the efficiency of water use is below 50 percent (53).

### Environmental Impacts

The two major environmental impacts from irrigation are: 1) the excessive use of groundwater in relatively dry areas, depleting aquifers; and 2) the improper design and management of irrigation projects, which can result in salinization, alkalinization, and waterlogging of fertile agricultural land.

Massive amounts of money have gone into the development of irrigated agriculture throughout the world. As a result, in certain areas where surface water is limited or legally difficult to use, groundwater reserves have been mined at a rate that exceeds their natural recharge. (See Table 8.7.) In North Africa and Saudi Arabia, socioeconomic development has been based, to a certain degree, on the use of fossil groundwater (which is essentially

**Table 8.6 Growth in Irrigated Area by Continent, 1950–85**

| | Total Irrigated Area (million hectares) | Growth in Irrigated Area[a] (percent) | | |
|---|---|---|---|---|
| **Region** | **1985** | **1950-60** | **1960-70** | **1970-80** |
| Africa | 13 | 25 | 80 | 33 |
| Asia[b] | 184 | 52 | 32 | 34 |
| Europe[c] | 29 | 50 | 67 | 40 |
| North America | 34 | 42 | 71 | 17 |
| South America | 9 | 67 | 20 | 33 |
| Oceania | 2 | 0 | 100 | 0 |
| **World** | **271** | **49** | **41** | **32** |

**Notes:**
a. Percentage increase between 1970 and 1982 prorated to 1970-80 to maintain comparison by decade.
b. Includes the Asian portion of the USSR.
c. Includes the European portion of the USSR.
**Source:** Adapted from Rangeley, 1985, Reference 51.

**Table 8.7 Selected Cases of Excessive Water Withdrawals**

| Region | Status |
|---|---|
| Colorado River Basin, United States | Yearly consumption exceeds renewable supply by 5 percent, creating a water deficit; Colorado River is increasingly salty; water tables have fallen precipitously in areas of Phoenix and Tucson. |
| High Plains, United States | The Ogallala, a fossil aquifer that supplies most of the region's irrigation water, is diminishing; over a large area of the southern plains, the aquifer is already half depleted. |
| Northern China | Groundwater overdrafts are epidemic in northern provinces; annual pumping in Beijing exceeds the sustainable supply by 25 percent; water tables in some areas are dropping up to 1–4 meters per year. |
| Tamil Nadu, India | Heavy pumping for irrigation has caused drops in water table of 25–30 meters in a decade. |
| Israel; Arabian Gulf; coastal United States | Intrusion of sea water from heavy pumping of coastal aquifers threatens to contaminate drinking water supplies with salt. |
| Mexico City; Beijing, China; Central Valley; California; Houston-Galveston, Texas | Groundwater pumping has caused compaction of aquifers and subsidence of land surface, damaging buildings, streets, pipes, and wells; hundreds of homes in a waterfront Texas community have been flooded. |

**Source:** Adapted from Postel, 1985, Reference 26.

non-renewable), since surface water is scarce and in some cases unusable (54). Globally, roughly only 0.1 percent of the total reserves of groundwater are rechargeable and can therefore be exploited on a sustainable basis (55). In addition to such limited availability, there are severe stresses on its quality.

In the southwest United States, the failure to place water on a sustainable footing threatens the viability of the resource base and consequently the economic system dependent upon it (56). Degraded aquifers have been reported from all over the continental United States. (See Figure 8.10.) And there is growing concern that large areas of irrigated agriculture throughout the western half of the country will collapse, unless water management strategies are worked out in combination with agricultural techniques better suited to drier climates. One fifth of the irrigated cropland in the United States is supported by groundwater mined from the vast Ogallala aquifer, which underlies portions of eight states on the high plains (57). (See Table 8.7.)

Excessive groundwater pumping has been reported from many other parts of the world as well. In the Tamil Nadu state of India, the groundwater table has plunged by over 25 meters since the 1930s (58). Likewise, in northern China, around Beijing, groundwater supplies have been overdrawn by 25 percent above the renewable supply, dooming plans to increase agricultural production (59).

During the 1960s, scientists generally became aware of the large amounts of chemical compounds generated by badly planned and executed irrigation projects, as well as by certain industrial uses. The mismanagement of irrigation schemes, in particular, leads to the "sterilization" of some of the best and most productive soils (60). This has been a persistent problem, even in such highly developed regions as the San Joaquin Valley of California. Unfortunately, the frequent decision to postpone the construction of expensive drainage systems to a later stage of an irrigation project means that short-term financial constraints get transformed into long-term, even more expensive resource degradation problems.

Globally, some 1–1.5 million hectares of mostly prime agricultural land are salinized every year (61). Since the beginning of modern civilization, the total amount of land affected by salinization from both anthropogenic and natural factors has been estimated at 20–30 million hectares (62).

In the United States alone, it is reckoned that 20–25 percent of all irrigated land (some 4 million hectares) suffers from salinization (63). And it is a persistent problem in the plains of eastern and western China, the Indian sub-continent, Central Asia and Asia Minor, the Aral-Caspian lowlands, the Caucasus and southeastern Europe, the Middle East, North and West Africa, and the plains of North and South America.

The best irrigation water from rivers still contains 200–500 milligrams per liter (mg/l) of salts. Supplying 10,000 cubic meters of water deposits in the soil anywhere from two to five tons of salt per hectare of land. After 10–20 years of irrigation the salt load becomes enormous, amounting to dozens and even hundreds of tons per hectare, rendering the land unfit for agricultural production (64).

This process of salinization can become a "vicious cycle." When water is diverted from a river or stream for irrigation, as much as 50 percent of it is not used by the crops. Instead, it seeps out of unlined canals, pipes, and ditches, runs off fields, or percolates through the soil. Most of this water eventually finds its way back to a river or to groundwater reservoirs. On its way through the soil, water dissolves naturally occurring salts in the rocks and soils and carries it along to rivers or groundwater aquifers, increasing their salinity. In the Colorado River Basin, for example, irrigation causes nearly 85 percent of all "man-induced salinity" (65).

Repeated and excessive use of water for irrigated crops also results in the eventual accumulation of salts in the upper layers of the soil, particularly if the irrigation water itself contains elevated amounts of salt. However, to maintain crop yields, these salts must be leached out of the root zone.

In order to avoid salt accumulation in the soil, the input of salts from the irrigation water must be balanced by a corresponding outflow of salts with the drainage water from the irrigated land (66). Drainage is also important because irrigated land often suffers from rising water tables. A balance has to be maintained in order to avoid waterlogging due to the accumulation of groundwater in the root zones of the crops. By keeping the groundwater level deep enough, evaporation near the surface, which contributes to salinization, can be prevented.

Lack of adequate drainage in irrigated lands remains one of the most serious problems: waterlogging of the soil is as damaging as salinization and they often go hand in hand. By 1990, an estimated 890,000 hectares of highly productive land in the San Joaquin Valley of California will have water tables a mere 1.5 meters deep, requiring that some 650,000 hectares be drained properly in order to remain productive (67). Rising water tables constitute a persistent problem for irrigated agriculture, but proper drainage schemes can usually eliminate waterlogging.

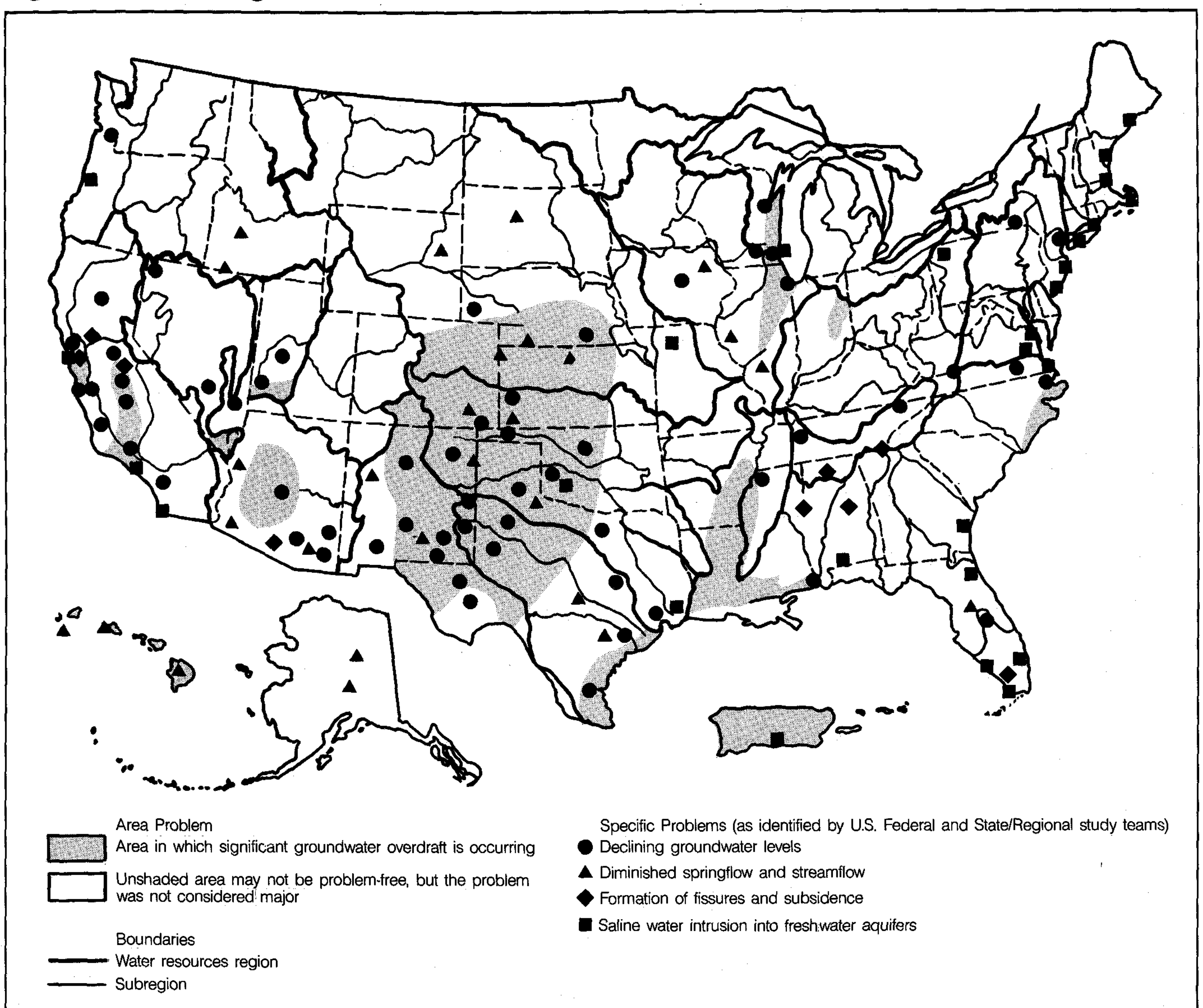
In the Colorado River Basin (southwestern United States), large amounts of excess irrigation water have added to the increasing salinization of the river itself (68). Increased salinity at the Mexican border led to a confrontation between the United States and Mexico, which eventually forced the United States to construct a desalinization plant at the border (69). Salt damage in the U.S. part of the Colorado River Basin still costs all users more than $113 million a year (70).

Similarly, in Israel, with its intensive program of groundwater recycling for irrigation, increasing groundwater salinity has been reported due to the accumulation of soluble minerals rejected by the crops (71). The problem threatens the survival of economically vital citrus groves and avocado plantations.

Soviet scientists report that both the Caspian and Aral Seas are in retreat from irrigation schemes that tap excessive amounts of water from their watersheds. The Aral Sea, in particular, is shrinking dramatically in size—the water level has dropped 3 meters since 1960, reducing the sea's size by some 18,000 square kilometers (72). By the year 2000, if present trends continue and more land is irrigated, its level will drop 9–13 meters below its original level (73). The Caspian Sea is not only suffering from falling water levels due to irrigation and industrial uses, but it is filling up with silt as well. As a result, the catch of sturgeon—and consequently the production of caviar—has been reduced, cutting into an industry that provides needed foreign currency.

Massive amounts of salts have been monitored in the irrigated basins of the Aral Sea (74). Complete use of regional stable runoff for crop production may permit a

**Figure 8.10 Declining Groundwater Levels and Related Problems in the United States**




**Source:** V.J. Pye, *et al.*, *Groundwater Contamination in the United States* (University of Pennsylvania Press, Philadelphia, 1983).

doubling of the present irrigated areas, and if the proposed water transfers from the Siberian rivers materialize, the irrigated areas around the Caspian and Aral Seas may expand sixfold. However, the reduced river flow to the Aral Sea has already increased its salinity threefold, to one gram per liter (75). By the year 2000, the salinity is expected to increase further, up to 3.5 grams per liter. The reduced flows to the Aral Sea may mean that the salts will have to accumulate elsewhere, and in the end, the second largest inland sea in the Soviet Union is expected to be converted into a small salty lake. The tragedy of the situation is underlined by estimates that suggest that the diversion of the Siberian rivers south into the Aral Sea Basin will still supply only about 25 percent of the estimated water deficiencies (76).

## PRICING

The general misconception that freshwater is a free and endless resource has seriously delayed society's need to adapt to the limits of a fixed supply (77). Lack of appropriate pricing policies only encourages the inefficient and wasteful use of existing reserves. In developed countries, industrial water use is declining, in part because of better pricing systems as well as water quality concerns. Studies carried out in the United States in the early 1970s clearly demonstrated that the cost of water was a prime factor in its use. At a very low price for water (around one cent per 1000 gallons), a fossil fuel-fired, steam, electric generating plant would use as much as 50 gallons per kilowatt hour (kWh) of electricity generated. As the price increased to five cents per 1,000 gallons, the plant would switch to a cooling tower, reducing raw water demand to about 0.8 gallons per kWh—a decrease of almost two orders of magnitude. If the price of water were to go to $8 per 1,000 gallons in dry regions, then a dry cooling tower, with effectively zero water use, would be the most economical technology to employ (78). In other words, from the western U.S. experience, a fivefold increase in the price of water leads to a fiftyfold decrease in use (79).

The same is true for municipal water uses. In the United States, studies have shown that consumers use substantially less water in municipal systems that have meters and higher prices. It has been demonstrated that a 10 percent increase in the price of water will result in a 1.5–7 percent drop in water demand (80).

Additionally, there is a direct correlation between the cost of water and irrigation efficiency. The U.S. Bureau of Reclamation found that at a cost of $1–3 per acre-foot of water, irrigation efficiency was less than 40 percent, but as the cost of water increased to $10 per acre-foot, irrigation efficiency improved to over 60 percent (81).

## EMERGING TRENDS IN WATER USE

As recently as the late 1960s, a few experts were projecting drastic increases in water use by the turn of the century—up to 15,000 cubic kilometers per year (82). Even if these estimates prove unrealistic, it is obvious that water demands are increasing. A number of experts conclude that as water demand increases, groundwater reserves will start to be mined at a greater rate. During the past 20 years, groundwater development has increased noticeably in Mexico, the United States, and Canada. Groundwater supplies more than 10 percent of Canada's drinking water, and in 1980, the United States withdrew 124 $km^3$ of groundwater for all purposes (83), up from 47 $km^3$ in 1950 (84). This trend is expected to continue into the next century.

As developing countries expand both agricultural and industrial activities over the next 20 years, there will be considerable pressure to increase pumping from underground reservoirs. And if their supplies consist mostly of fossil groundwater, then some water-short countries could end up mining a non-renewable resource; it takes thousands and sometimes millions of years to replenish fossil groundwater stocks.

## WATER POLLUTION

Since the dawn of history, humankind has manipulated the freshwater system in order to augment dependable supplies by pumping, piping, channeling, damming, storing, draining, and tilling. In other words, human activities have proved to be an integral part of the water cycle (85).

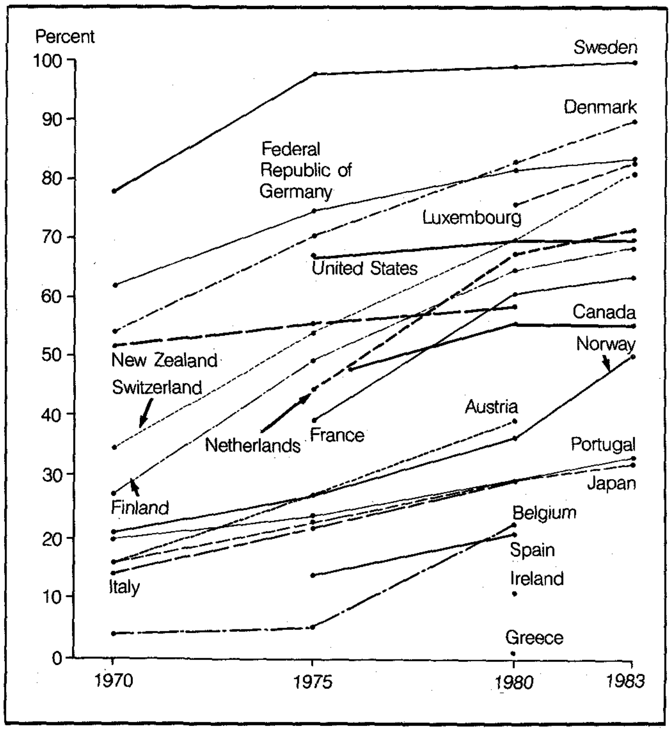
In Europe and the United States, where industrial development took place under relatively water-rich conditions, the wastes were returned to the rivers, generating adverse environmental effects. As water demands increased for municipalities, industry, hydropower, and waste treatment and as vast land reclamation projects were developed, the quality of the water in aquifers, rivers and streams, and lakes began to deteriorate.

The fouling of water courses and lakes by industrial processes and sewage treatment has been one of the hallmarks of this century, but the process has accelerated rapidly, especially since the Second World War. Consequently, water pollution issues have attracted active public interest in many regions of the world.

The basic type of water pollution, well known in both developed and developing countries, is the pollution caused by the discharge of untreated or inadequately treated waste water into rivers, lakes, and reservoirs. Over much of the industrialized world, waste water treatment plants employing various technologies have been installed at considerable costs to reduce the discharge of polluted effluents into freshwater systems. Figure 8.11 shows a consistent upward trend in the number of people served by waste water treatment plants in the Organization for Economic Co-operation and Development (OECD) countries, although there is considerable variation in the percentage of the population covered: from 20 percent for Spain and Belgium to nearly 100 percent in Sweden. In the developing world, however, the trends are just the opposite—as their rudimentary industrial bases take shape and populations expand, water pollution control and waste water and sewage treatment are either non-existent or are wholly unable to keep pace with levels of pollution (86).

As industrial waste water flows increase and become more complex, with higher loads of inorganic and toxic chemical compounds, new pollution problems develop.

**Figure 8.11 Percentage of Population Served by Waste-Water Treatment Plants, 1970–83**




**Source:** Organization for Economic Co-operation and Development (OECD), *State of the Environment 1985* (OECD, Paris, 1985).

Local fish-kills attributable to the effects of toxic substances in the water become commonplace. In order to minimize these pollution effects, most developed countries such as Sweden, as mentioned earlier, used legislation to force technical improvements in the way municipalities and industries treat and dispose of their waste products (87). On the other side of the ledger, developing countries like India, China, Indonesia, Tanzania, and Kenya are among those Third World nations suffering from an increase in industrial pollution of their freshwater systems.

Another water quality problem is the increasing eutrophication of rivers and lakes, despite municipal waste water treatment. This type of pollution, called nonpoint pollution, is caused mainly by the runoff of pesticides, herbicides, and fertilizers from agricultural lands (88). Since the 1950s, there has been a marked increase in the concentration of phosphate (phosphorous) and nitrates in the inland waters of many countries, particularly North America and Europe. This rise reflects the increased use of detergents and fertilizers. Two of the most notable cases of eutrophication involve Lake Balaton in Hungary and Lake Geneva (wedged between France and Switzerland). Both lakes suffer from an overdose of nutrients brought in by the chemical runoff from nearby agricultural lands, mainly vineyards and farmland. Eutrophication is also a major problem in reservoirs and artificial lakes used for community water supplies, particularly in Morocco and many countries in Latin America.

The overall quality of the water in rivers and streams of OECD countries—as measured by the amount of dissolved oxygen in a river or lake and the amount of biological oxygen demand (BOD) from the introduced waste—has improved since the 1970s (89). (See Table 8.8.) By and large there is more dissolved oxygen in the rivers of OECD countries than in the 1970s, pointing to the effects of clean water legislation, particularly the introduction of secondary (biological) and tertiary (chemical) treatment of waste water. This trend is further confirmed by national surveys, which show reductions in the discharge of oxygen-consuming substances and improvements in the water quality of many rivers in the United States, Japan, France, the Netherlands, the United Kingdom, and the Nordic countries (90). Nevertheless, stretches of some rivers in these same countries are still polluted.

The 42 rivers monitored in the OECD countries since 1970 have also shown a consistent improvement as regards certain other pollutants. The measurable amounts of ammonium have decreased along with those for heavy metals like lead and cadmium. In the Rhine River (at a site in West Germany), lead, in fact, has shown a dramatic decrease, from 24 micrograms per liter ($\mu$g/l) in 1975 to 8 $\mu$g/l in 1983 (91). Over the same period, cadmium in the Rhine (at the same site) declined from 2.40 $\mu$g/l in 1975, to only 0.40 $\mu$g/l in 1983 (92).

Similar data for developing countries are nearly nonexistent, but scattered reports and the few monitoring data available indicate that pollution is a growing problem. India is a classic example: 70 percent of its total surface waters are polluted (93). Out of India's 3,119 towns and cities, only 217 have partial (209) or full (8) sewage treatment facilities (94). The result is severely contaminated waters. A 48-kilometer stretch of the Yamuna River, which flows through New Dehli, contains 7,500 coliform organisms per 100 milliliters (ml) of water before entering the capital, but after receiving an estimated 200 million liters of untreated sewage every day, it leaves New Dehli carrying an incredible 24 million coliform organisms per 100 ml (95). Industry is no better. That same stretch of the Yamuna River picks up 20 million liters of industrial effluents, including about 500,000 liters of "DDT wastes" every day (96).

China's rivers also seem to be suffering from increasing pollution loads. Of the 78 monitored rivers in the People's Republic, 54 are reported to be seriously polluted with untreated sewage and industrial wastes. The Huangpujian River, a major source of drinking water for Shanghai, carries one volume of untreated wastes for each four to six volumes of water (97). Malaysian rivers, in turn, are becoming ecological disasters. Reports indicate that more than 40 major rivers are so polluted that they are nearly devoid of fish and aquatic mammals. The primary pollutants were identified as oil palm and rubber processing residues, sewage, and industrial wastes (98).

Rivers in the Soviet Union are becoming more polluted as industries expand. Industrial waste waters are said to comprise a full 10 percent of the Volga River's average flow at Volgograd, with three quarters of the wastes discharged into the river untreated (99).

**Table 8.8 Water Quality Indicators for Selected Rivers, 1970–83**
*(milligrams per liter)*

| | | Dissolved Oxygen (DO)[a] | | | | | Biological Oxygen Demand (BOD)[a] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1970 | 1975 | 1980 | 1983 | Average Last 3 Years Avail. | 1970 | 1975 | 1980 | 1983 | Average Last 3 Years Avail. |
| Canada | St. Lawrence | 8.1 | 10.0 | X | X | X | X | X | X | X | X |
| United States | Delaware-Trenton | 9.6 | 10.8 | 11.9 | 10.3 | 11.1 | 1.9 | 2.0 | 2.2 | 2.6 | 2.8 |
| | Mississippi-St. Francis | 8.4 | 8.5 | 8.3 | 8.9 | 8.9 | 2.4 | 2.2 | 1.7 | 1.1 | 1.8 |
| Japan | Ishikari | 8.7 | 10.7 | 10.6 | 10.6 | 10.5 | 1.7 | 1.4 | 1.4 | 1.5 | 1.4 |
| | Yodo | 8.3 | 8.9 | 9.0 | 8.2 | 8.0 | 3.6 | 3.2 | 3.8 | 4.2 | 4.1 |
| Australia | Brisbane Estuary[b,c] | X | 5.6 | 6.4 | 6.0 | 6.2 | X | 1.6 | 1.0 | 1.2 | 1.2 |
| New Zealand | Waikato[d] | X | 9.0 | X | X | X | X | 1.5 | X | X | X |
| Belgium | Meuse-Heer/Agi.[e] | 8.2 | 10.8 | 10.6 | X | 10.7 | 4.4 | 6.6 | 4.2 | X | 4.7 |
| | Meuse-Lanaye[f] | 7.7 | 8.9 | 9.5 | X | 9.2 | 12.5 | 4.7 | 3.9 | X | 4.0 |
| | Escaut-Bleharies | X | 4.0 | 5.9 | X | 4.7 | X | 24.1 | 10.7 | X | 9.6 |
| | Escaut-Doel[e] | 6.2 | 1.3 | 1.9 | X | 2.1 | 4.0 | 8.2 | 5.0 | X | 14.0 |
| Denmark | Gudenaa | X | X | 9.7 | 10.7 | 10.2 | X | X | 3.4 | 4.5 | 4.3 |
| | Skjernaa[g] | X | X | 10.5 | 10.4 | 10.4 | X | X | 7.3 | 8.0 | 8.3 |
| | Susaa | X | X | X | 8.7 | 9.1 | X | X | X | 2.0 | 2.1 |
| Finland | Tornionjoki | 11.9 | 11.9 | 12.0 | X | 11.9 | 1.6 | 1.6 | X | X | 1.7 |
| | Kymijoki | 9.5 | 10.8 | 9.9 | X | 10.8 | 3.5 | 2.4 | X | X | 2.5 |
| France | Loire-Nantes[e,h] | 10.7 | 11.1 | 11.8 | 12.0 | 11.6 | 6.7 | 4.4 | 6.6 | 6.7 | 6.0 |
| | Seine-Tancarville[e,h] | X | 3.3 | 4.9 | 5.9 | 5.2 | X | 10.2 | 6.6 | 4.1 | 4.9 |
| | Garonne-Bordeaux[e,h] | 9.7 | 9.9 | 10.1 | 9.9 | 9.9 | 2.2 | 1.5 | 2.3 | 2.3 | 2.1 |
| | Rhine-Selz[e] | 8.2 | 9.2 | 10.9 | 8.6 | 8.9 | X | 4.1 | 4.8 | 3.0 | 3.6 |
| Germany | Rhine-Bimmen L. | 5.6 | 6.5 | 8.4 | 9.1 | 9.0 | 6.1 | 6.9 | 3.6 | 3.5 | 3.6 |
| Italy | Po[i] | X | X | X | X | X | X | 7.3 | 7.3 | X | 7.2 |
| Netherlands | Meuse-Keizersveer | 8.6 | 9.4 | 10.0 | 9.7 | 9.8 | 6.2 | 4.2 | 2.3 | 2.0 | 2.3 |
| | Meuse-Eijsden | 9.8 | 9.5 | 9.8 | 8.7 | 9.1 | 4.1 | 3.7 | 2.8 | 2.8 | 2.8 |
| | Scheur-Maasluis | X | 7.1 | 8.1 | 8.7 | 8.5 | X | 3.3 | 2.2 | 1.5 | 1.9 |
| | Ijssel-Kampen | 6.7 | 6.7 | 8.1 | 8.2 | 8.4 | 5.7 | 6.3 | 3.9 | 2.3 | 2.7 |
| Norway | Skienselva | X | X | X | 6.0 | X | X | 2.5 | 3.5 | X | X |
| Portugal | Tejo | 9.0 | X | 9.0 | X | X | 1.6 | X | 2.5 | X | X |
| Spain | Guadalquivir[b,g] | X | X | X | X | X | X | 12.3 | 11.8 | X | 8.2 |
| Switzerland | Rhine-Village | 11.6 | 11.2 | 10.3 | 10.2 | 10.4 | X | X | X | X | X |
| | Aare-Brugg[b,g] | X | 10.2 | 10.2 | X | 10.4 | X | X | X | X | X |
| | Limmat-Baden[e] | X | X | 9.1 | X | X | X | X | X | X | X |
| | Rhone-Port du Scex[b,g] | X | 10.7 | 10.9 | X | 11.0 | X | X | X | X | X |
| United Kingdom | Thames | X | 10.8 | 9.9 | 9.8 | 9.9 | X | 4.2 | X | X | 4.0 |
| | Severn | X | 10.5 | 10.3 | 11.5 | 10.7 | X | 3.9 | X | X | 3.2 |
| | Clyde | X | 7.7 | 9.4 | 8.4 | 8.5 | X | 7.3 | 5.6 | X | 5.3 |
| | Mersey | X | 5.1 | 6.1 | 6.1 | 6.1 | X | 8.6 | X | X | X |
| Yugoslavia | Dunau | 9.6 | 9.1 | 9.2 | X | 9.5 | 3.4 | 2.5 | 3.5 | X | 3.7 |
| | Drava | 8.8 | 7.4 | 10.1 | X | 10.0 | 3.4 | 2.6 | 3.1 | X | 3.1 |

X = not available
**Notes:**
a. Measured at the mouth or downstream frontier of river.
b. 1975 data refer to 1976.
c. Data refer to fiscal year (i.e., 1983 refers to 1982–83).
Data for the same indicator may not be comparable because of measurements by different authorities; 1972–75 data are not comparable with those of later years because of different recording methods.
d. Data are approximate.
e. 1970 data refer to 1971.
f. 1970 data refer to 1972.
g. 1980 data refer to 1979.
h. 1983 data refer to 1982.
i. 1980 data refer to 1978.
**Source:** Organization for Economic Co-operation and Development (OECD), 1985, Reference 89.

## Polluted Groundwater

Nitrate concentrations in groundwater reserves have been increasing for the past decade, giving rise to health concerns (100). Today, elevated levels of nitrates in drinking water—from both natural and anthropogenic sources—are considered among the worst forms of groundwater pollution facing Europe and North America. With the increasing use of fertilizers in the Third World, similar problems are expected to crop up during the next decade in the South. According to a recent assessment, forests, dry steppes, and semi-arid areas under temperate conditions carry higher risks of nitrate leaching than similar areas in tropical climates, which should have fewer problems with nitrates in drinking water (101).

The disposal of human wastes from septic tanks and agricultural activities, including fertilizers and wastes from livestock, are the two largest sources of nitrate contamination of groundwater throughout the United States. (See Figure 8.12.) Recent surveys indicate that out of more than 124,000 wells sampled, 24,000 (20 percent) had water with maximum nitrate-nitrogen concentrations greater than 3 mg/l (102). Of these wells, some 8,200 had nitrate-nitrogen concentrations that exceeded the U.S. Environmental Protection Agency's regulatory limit of 10 mg/l. The U.S. Geological Survey notes that "in most instances, elevated nitrate concentrations occurred in water from wells in shallow aquifers, although long-term increases of nitrate in deep aquifers are possible where the aquifers are recharged by nitrate-rich water from shallow aquifers or from the land surface" (103).

The pollution threat in Europe and North America is also aggravated by the seepage of toxic chemicals from waste dumps that slowly percolate into the groundwater table. In the United States, some 10–20 percent of the 10,000 identified dump sites for hazardous wastes are considered a potential threat to groundwater reserves (104). City dumps (called "sanitary landfills") containing household garbage and solid wastes also produce leachate that can infiltrate groundwater systems.

China reports that 41 out of 44 large cities suffer from polluted groundwater. This pollution is thought to be responsible for the high levels of heavy metals monitored in urban and suburban vegetable gardens (105).

Similarly, European countries are suffering from increased levels of toxic substances seeping into groundwater reservoirs (106).

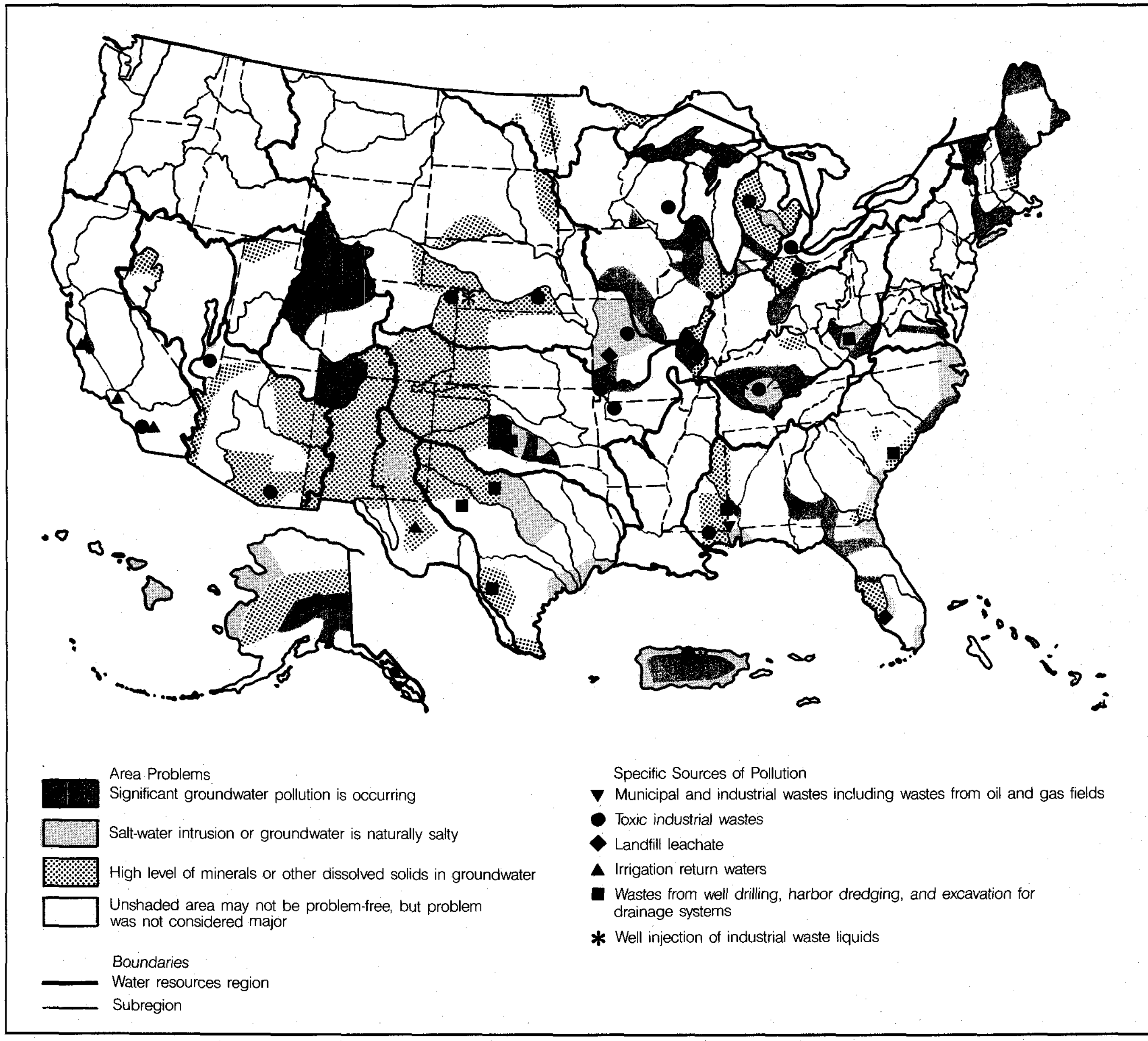
In order to prevent groundwater contamination in the future, policymakers must clearly grasp the processes involved. Groundwater pollution, which is the result of a long-term process, must be detected at an early stage. Because of the very slow rate at which groundwater moves, once groundwater is polluted and unfit for consumption, it might take decades, centuries, or even millenia before natural processes flush out the pollution (107).

## A LOOK AHEAD

Managing water demand instead of increasing supplies will become extremely important over the course of the next two decades. Water-efficient technologies in agriculture and industry must be developed and widely used if humankind is to avoid a worsening water crisis in the coming decades, especially in water-poor regions.

Irrigation efficiencies, which now stand at a world average of only 37 percent (mostly due to overirrigation and to transport losses), must be increased. Obviously, there is much scope for improvement. Better management of canal systems alone will reduce water losses from irrigation in the Third World by 10–15 percent.

**Figure 8.12 Groundwater Pollution in the United States**




**Source:** V.J. Pye *et al., Groundwater Contamination in the United States* (University of Pennsylvania Press, Philadelphia, 1983).

In order to accomplish better management of water resources, water pricing may emerge as one of the best tools, along with further government regulation and education.

## RECENT DEVELOPMENTS

### INTERNATIONAL DRINKING WATER AND SANITATION DECADE

The International Drinking Water and Sanitation Decade (1981–90), launched by the United Nations in 1980, is creating a global awareness among policymakers of the importance of potable water in the fight against disease by promoting and strengthening public sector institutions in managing water resources (108). But translating the ambitious goal of bringing freshwater and proper sanitation to all by the year 1990 would necessitate the provision of water supplies for 500,000 people every day during the entire decade (109). To achieve this goal in a mere 10 years is proving unrealistic.

Still, it is an urgent need for public health reasons, as well as to end malnutrition. Infections from unclean water can cause malnutrition despite an adequate calorie supply. Coordinated education in sanitation, nutrition, and health is essential (110).

### THE INTERDEPENDENCE OF LAND AND WATER

At a recent seminar on "River Basin Strategy," sponsored by the International Water Resources Association (IWRA), water experts from semi-arid zones called for an integrated approach to water management to meet the dual problems of soil and water degradation from land-based activities. It is apparent that the "water illiteracy" prevalent among planners needs to be overcome if new strategies are to be implemented to deal with the narrowing gap between supplies and consumption in water-scarce regions (111).

From a policy perspective, attention is also being focused on the whole field of watershed management. International assistance is stressing the importance of land conservation as a measure of disaster prevention, bringing water conservation as one of its main benefits. An international conference held in Ibadan, Nigeria, in 1979 on "Tropical Agricultural Hydrology" drew attention to the technical solutions being tried successfully in various tropical environments. Problems remain unresolved in areas with heavily populated watersheds subjected to widespread subsistence farming and livestock raising (112).

A recent meeting in Lidingö, Sweden—"Innovation for Development"—was sponsored by the International Inventors Awards. Experts concluded that any innovations in the area of water management should address not only the existing constraints imposed by the hydrological cycle itself but those induced by steadily increasing water demands for industry and agriculture, by ongoing land degradation in catchment areas, and by worldwide water quality deterioration (113).

### MULTINATIONAL USE OF SHARED WATER RESOURCES

By the mid-1970s, around 40 percent of the world population was estimated to live in international river basins, that is, in countries dependent on imported (exogenous) water (114). The amount and quality of most of this water are controlled by activities in upstream countries: the larger the irrigation schemes in upstream countries, the less water there is for downstream uses; the larger the polluting activities in upstream countries, the poorer is the quality of water arriving in downstream countries.

The degree to which continental rivers are international in character varies considerably in response to geography, size of the countries, etc. (115). (See Table 8.9.) In Africa, for example, most of the river systems spill across national boundaries. This situation makes the African continent particularly sensitive to the problems of shared water resources. In several cases countries have mutual interests in increasing the dependable flow of water. Both Egypt and the Sudan, for example, have a vital stake in water storage and flow control schemes on the Nile (116).

The Rhine River, on the other hand, is a classic example of conflicting water quality interests. Both France and the Federal Republic of Germany use Rhine water for industrial purposes, discharging heavy pollution loads that the Dutch must clean downstream for drinking water. In India, the Ganges River is an example of where an upstream country diverts great quantities of river water for its own use (mainly for flushing out Calcutta harbor), thereby reducing the stable river flow for the downstream country of Bangladesh (117).

At the United Nations Water Conference in Mar del Plata, Argentina, in 1977, considerable interest was given to the issue of international river basins and the need for river basin authorities (118). Many downstream countries joined together in calling for an "international code of conduct" that would attempt to set guidelines or limits on how upstream and downstream countries could use their shared resource. There is clearly a need to strengthen the force of international law as an instrument to induce states into cooperative measures to safeguard common water resources. An "international code of conduct" would encourage countries to cooperate on more specific water use and water quality issues.

The United Nations Water Conference provided a number of countries—particularly Argentina, Egypt, Mexico, and Romania—with the impetus needed to formulate and

**Table 8.9 International Rivers By Continent**

| Continent | Population 1973 (millions) | International River Basins | River Basins Shared by Four or More Countries | Number of Treaties 1972 |
|---|---|---|---|---|
| Africa | 270 | 56 | 12 | 34 |
| North and Central America | 90 | 34 | | 38 |
| South America | 100 | 36 | 2 | 31 |
| Asia | 600[a] | 40 | 5 | 31 |
| Europe | 330 | 48 | 4 | 175 |
| **Total** | **1390[a]** | **214** | **23** | **309** |

**Note:** a. Data are approximate.
**Source:** Widstrand, 1980, Reference 114.

implement long-range planning based on "demand projections, comprehensive river basin planning and water economy budgets" (119).

Over the decade from 1975 to 1985, there was a discernible trend toward the establishment of river basin authorities such as the ones in the Sokoto River Basin in Nigeria and the Volta Basin in Burkina Faso (120). Developed countries also expanded their management capacities. In the United Kingdom, for example, the government established a network of regional water authorities responsible for supply, conservation, and waste water treatment (121).

## WATER LAW

Water law also gained importance in both developed and developing countries over the same period. At least one third of all countries in the world revised their administrative and statutory arrangements for regulating water resources. These embraced water rights, water and land control, pollution, and waste water treatment (122).

From 1972 to 1982, the international community enlarged its research and educational capabilities. Three efforts stand out: the creation of the Water Research Centre in the United Kingdom; the establishment of the Institute of Water Economics, Legislation and Administration in Latin America; and the founding of the International Training Center for Water Resources Management in France (123).

Since the founding of the United Nations Environment Program in 1972, major new water pollution control statutes were enacted in the United States, New Zealand, the Federal Republic of Germany, Greece, Ireland, Italy, the Netherlands, Spain, the United Kingdom, and the Soviet Union (124).

## References and Notes


1. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), *State of the Environment in Asia and the Pacific*, Vol. 2 (UNESCAP, Bangkok, 1984), p. 122.
2. V. Giacomini and D. Hinrichsen, "New Perspectives on the Eternal City," *AMBIO*, Vol. 10, Nos. 2–3, p. 80 (1981).
3. M. Falkenmark, "Water and Mankind—A Complex System of Mutual Interaction," *AMBIO*, Vol. 6, No. 1, p. 3 (1977).
4. *Ibid.*
5. A.K. Biswas, Ed., *Water Development Supply and Management, United Nations Water Conference: Summary and Main Documents*, Vol. 2, Mar Del Plata, Argentina, March 1977 (Pergamon Press, Oxford, 1978), p. 38.
6. M. Falkenmark, "New Ecological Approach to the Water Cycle: Ticket to the Future," *AMBIO*, Vol. 13, No. 3, p. 157 (1984).
7. J. Forkasiewicz and J. Margat, *Tableau Mondial de Données Nationales D'Economie de L'Eau, Ressources et Utilisations* (Départment Hydrogéologie, 79 SGN 784 HYD, Orléans, France, 1980).
8. *Op. cit.* 7; and M. Falkenmark, "Macro-Scale Water Supply/Demand Comparison on the Global Scene—A Hydrological Approach," in *Hydrology and Earth Sciences* (Beitrage zur Hydrologie, 1986, in press).
9. *Op. cit.* 6.
10. A. Baumgartner and E. Reichel, *The World Water Balance* (Elsevier, Amsterdam, 1975).
11. A.K. Biswas, "Climate and Water Resources," in *Climate and Development*, Vol. 13, A.K. Biswas, Ed. (Tycooly International Publishing Ltd., 1984).
12. A.V. Todorov, "Sahel: The Changing Rainfall Regime and the 'Normals' Used for Its Assessment," *Journal of Climate and Applied Meteorology*, Vol. 24, No. 2, p. 102 (1985).
13. *Renewable Resource Trends in East Africa* (Program for International Development, Clark University, 1984), p. 64.
14. P. Rogers, "Freshwater," background paper prepared for the conference, *The Global Possible, Resources, Development and the New Century* (World Resources Institute, May 2–5, 1984), p. 12.
15. *Op. cit.* 1, p. 122.
16. M.J. Dourojeanni, *Renewable Natural Resources of Latin America and the Caribbean: Situation and Trends* (World Wildlife Fund-U.S., Washington D.C., 1982), p. 224.
17. *Op. cit.* 5, p. 39.
18. R.P. Ambroggi, "Water," *Scientific American*, p. 103 (September 1980).
19. *Op. cit.* 14, p. 53.
20. *Ibid.*, p. 14.
21. *Ibid.*
22. *Ibid.*, p. 44.
23. *Ibid.*, p. 53.
24. *Op. cit.* 5, p. 40.
25. International Institute for Environment and Development (IIED), *Natural Resources and Economic Development in Central America* (IIED, Washington, D.C., 1985), p. 41.
26. S. Postel, "Managing Freshwater Supplies," in *State of the World 1985* (Norton, New York, 1985), p. 42.
27. United Nations Environment Program (UNEP), *The State of the World Environment: 1972–82* (UNEP, Nairobi, January 29, 1982), p. 22.
28. E. Fano and M. Brewster, "Industrial Water Pollution Control in Developing Countries," in *Water Resources Management in Industrial Areas*, 1982, p. 219.
29. *Op. cit.* 14, p. 26.
30. *Op. cit.* 7.
31. Municipal uses of water include drinking water, household water, water for sanitation and sewage treatment, and water for commercial use. The term includes both urban and rural communities.
32. *Op. cit.* 1, p. 127.
33. World Health Organization (WHO), *Decade Dossier* (International Drinking Water Supply and Sanitation Decade 1981–90, WHO, Geneva, 1981), p. 4.
34. M. Falkenmark, "Needed: A Water Strategy for the 1980s," *AMBIO*, Vol. 10, No. 1, p. 47 (1981).
35. N.D. Jayal, "Destruction of Water Resources—The Most Critical Ecological Crisis of East Asia," *AMBIO*, Vol. 14, No. 2, p. 96 (1985).
36. World Health Organization (WHO), *The International Drinking Water Supply and Sanitation Decade: Review of National Baseline Data* (WHO, Geneva, 1984), p. 13.
37. *Ibid.*
38. *Ibid.*
39. *Op. cit.* 5, p. 48.
40. *Op. cit.* 16, p. 231.
41. *Op. cit.* 35, p. 96.
42. H. Osore, "Pollution and Public Health in East Africa," *AMBIO*, Vol. 12, No. 6, p. 318 (1983).
43. *Op. cit.* 36, pp. 44–45.
44. *Op. cit.* 5, p. 52.
45. *Ibid.*
46. *Op. cit.* 27.
47. *Op. cit.* 14, p. 27.
48. *Ibid.*
49. M. Falkenmark, "Reduced Water Demand—Result of Swedish Anti-Pollution Program," *AMBIO*, Vol. 6, No. 1, p. 66 (1977).
50. M.I. L'vovich, *World Water Resources and Their Future* (translated by the American Geophysical Union, LithoCrafters Inc., Chelsea, Michigan, 1979), p. 250.
51. W.R. Rangeley, "Irrigation and Drainage in the World," (unpublished paper, 1985), p. 9.
52. *Ibid.*, p. 8.
53. M.T. El-Ashry, "Groundwater Salinity Problems Related to Irrigation in the Colorado River Basin," *Groundwater*, Vol. 18, No. 1, p. 38 (1980).
54. J. Margat and K.F. Saad, "Deep-Lying Aquifers: Water Mines under the Desert?," Nature and Resources, No. 2, p. 10

(1984).
55. *Op. cit.* 5, p. 40.
56. *Op. cit.* 26.
57. *Ibid.*, pp. 51–52.
58. *Ibid.*, pp. 53–54.
59. *Ibid.*, p. 54.
60. V.A. Kovda, "Soil Reclamation and Food Production," in *Food, Climate and Man*, M.R. Biswas and A.K. Biswas, Eds. (John Wiley and Sons, London, 1979), p. 172; and V.A. Kovda, "Loss of Productive Land Due to Salinization," AMBIO, Vol. 12, No. 2, p. 91 (1983).
61. V.A. Kovda, "Loss of Productive Land Due to Salinization," *AMBIO*, Vol. 12, No. 2, p. 92 (1983).
62. *Ibid.*
63. M.T. El-Ashry, *et al.*, "Salinity Pollution from Irrigated Agriculture," *Journal of Soil and Water Conservation*, Vol. 30, No. 1, p. 48 (1985).
64. *Ibid.*, p. 49.
65. *Ibid.*
66. V.A. Kovda, "Soil Reclamation and Food Production," in *Food, Climate and Man*, M.R. Biswas and A.K. Biswas, Eds. (John Wiley and Sons, London, 1979), p. 172.
67. *Op. cit.* 63, p. 50.
68. *Op. cit.* 53, p. 39.
69. I.L. Murphy and J.E. Sabadell, "The Impact of Water Resources Public Policies on International River Basin Conflicts," in *Water Resources for Rural Areas and Their Communities* (Proceedings of the 5th World Congress on Water Resources, Brussels, Paper No. 229, Vol. 2, 1985), p. 883.
70. *Op. cit.* 63, p. 50.
71. H.I. Shuval, *The Impending Water Crisis in Israel, Developments in Arid Zone Ecology and Environmental Quality* (Balaban ISS, Philadelphia, 1981).
72. S. Trofimenko, "The State and Destiny of the Aral Sea," *AMBIO*, Vol. 14, No. 3, p. 181 (1985).
73. G.N. Golubev, "Economic Activity, Water Resources and the Environment: A Challenge for Hydrology," *Hydrological Sciences-Journal*, Vol. 28, No. 1, p. 57 (July 1984).
74. *Ibid.*
75. *Ibid.*
76. *Op. cit.* 26, p. 72.
77. C. Olsenius, "Public Water Management Initiatives: Three Case Studies," in *Water Resources for Rural Areas and Their Communities* (Proceedings of the 5th World Congress on Water Resources, Brussels, Paper No. 248a, Vol. 2, 1985), p. 977.
78. *Op. cit.* 14, p. 28.
79. *Op. cit.* 14, p. 28.
80. *Op. cit.* 14, p. 19.
81. *Op. cit.* 53, p. 28.
82. T.J. Buchanan, "Groundwater—Its Worldwide Importance" (unpublished paper, 1985), p. 5.
83. *Ibid.*, p. 9.
84. *Ibid.*, p. 15.
85. U.S. Geological Survey, *National Water Summary 1983—Hydrologic Events and Issues*, Water Supply Paper 2250 (U.S. Geological Survey, U.S. Government Printing Office, Washington, D.C., 1984).
86. *Op. cit.* 35, p. 95.
87. *Op. cit.* 49.
88. *Op. cit.* 5, p. 41; and *op. cit.* 73.
89. Organization for Economic Co-operation and Development (OECD), *OECD Environmental Data* (OECD, Paris, 1985), p. 55.
90. *Ibid.*, pp. 55–61.
91. *Ibid.*, p. 58.
92. *Ibid.*
93. Centre for Science and Environment, *The State of India's Environment, 1982* (Centre for Science and Environment, New Delhi, 1982), p. 17.
94. *Ibid.*
95. *Ibid.*, p. 20.
96. *Ibid.*
97. V. Šmil, "Ecological Mismanagement in China," *The Bulletin of the Atomic Scientists*, Vol. 38, No. 8, p. 22 (1982).
98. *Op. cit.* 35, p. 98.
99. *Op. cit.* 26, p. 51.
100. *Op. cit.* 73.
101. *Op. cit.* 73.
102. U.S. Geological Survey, *National Water Summary 1984* (U.S. Geological Survey, Water Supply Paper No. 2275, U.S. Government Printing Office, Washington, D.C., 1985), p. 3.
103. *Ibid.*
104. R.D. Hill, "Controlling the Epidemic of Hazardous Chemicals and Wastes," *AMBIO*, Vol. 12, No. 2, p. 86 (1983).
105. *Op. cit.* 97, p. 22.
106. For an excellent survey of toxic chemicals and their effects on groundwater (as well as on human health and environmental qualty), see *AMBIO*, Vol. 11, No. 1, pp. 46–69 (1982).
107. C.P. Young, "The Geology of Water Supplies," *Waterlines*, Vol. 3, No. 2, p. 23 (October 1984).
108. M. Falkenmark, Ed., *Rural Water Supply and Health, The Need for a New Strategy*, Summary of papers and discussions from the United Nations Interregional Seminar on Rural Water Supply, Uppsala, Sweden, October 6–17, 1980 (Scandinavian Institute of African Studies, Uppsala, 1983).
109. *Op. cit.* 34, p. 37.
110. M. Falkenmark and J. Lundqvist, Eds., "*Water for All: Coordination, Education, Participation*, Report from an international seminar Tema 5, Report 9, (University of Linköping, Sweden, 1984).
111. International Water Resources Association (IWRA), "Synthesis and Conclusions" in *River Basin Strategy*, IWRA Seminar, on River Basin Strategy Linköping, Sweden, June 1984, (GeoLibrary, 1985).
112. C. Pereira, "Land-Use Management on Tropical Watersheds," in *Tropical Agricultural Hydrology, Watershed Management and Land Use* (John Wiley and Sons, Oxford, 1979).
113. Working Group on Water, Report in *Innovation for Development* (Symposium, International Inventors Awards, Lidingö, Sweden, June 1983).
114. C. Widstrand, Ed. "Water Conflicts and Research Priorities, Water and Society, Conflicts in Development," *Water Development, Supply and Management*, Vol. 8 (Pergamon Press, Oxford, 1980).
115. *Ibid.*
116. M. Falkenmark, in *Global Resources and International Conflict*, A. Westing, Ed. (Stockholm International Peace Research Institute, Stockholm, 1986, in press).
117. *Ibid.*
118. *Report of the United Nations Water Conference*, Mar del Plata, Argentina, March 14–25, 1977 (United Nations, New York, 1977).
119. United Nations Environment Program (UNEP), *The World Environment 1972–1982* (UNEP and Tycooly International Publishing Ltd., Dublin, 1982), p. 159.
120. *Ibid.*
121. *Ibid.*
122. *Ibid.*
123. *Ibid.*
124. *Ibid.*, p. 150.

# 9. Oceans and Coasts

Oceans cover more than two thirds of the earth's surface and sustain numerous valuable living resources. Over half the population in the developing countries obtains 40 percent or more of its total animal protein supplies from fish (1). Fish products are also used for animal feed, for fertilizer, and in soaps, pharmaceuticals, and other commercial products.

## CONDITIONS AND TRENDS

Nearly all the world catch of marine species is taken within 320 kilometers of land, the zone where more than half the total biological productivity of the oceans occurs (2). Unfortunately, coastal areas are also subject to a variety of human pressures that could severely degrade the natural resource base.

## WORLD FISHERIES

### The Marine Fisheries Harvest

The total world fisheries catch has increased during the past few decades. Between 1950 and 1970, it rose steadily and rapidly at an annual rate of about 7 percent. (See Table 9.1.) Then between 1971 and 1972 the total catch dropped, largely due to the dramatic fall in the catches of Peruvian anchovy which was then by far the largest fishery in the world. Since 1972 the catch has been increasing again, but only at 1–2 percent annually. The present marine catch totals some 76 million metric tons annually.

Fisheries in the North Pacific and North Atlantic dominate the world's fish harvest, accounting for more than half the total catch. Formerly the home of the world's major fishing fleets, these areas continue to dominate because they are exceptionally well-endowed with the shallow continental shelves on which most commercial species are found.

The steady rise of the world total catch is not typical of the catch from individual fisheries, which may fluxuate. The typical history of exploitation of an individual stock is for catches to remain at a low level (or even zero) until the stock is located by a long-range fleet, or a technical or marketing development triggers the growth of a local fishery. Growth can then be very fast, doubling each year for a decade or more (as occurred with the Peruvian anchoveta). But this situation is exceptional; growth rates of 20 percent or even 50 percent per year are more common.

If the resource is fairly resilient under heavy exploitation, catches may reach an asymptote equal to the productive capacity of the resource. But less stable stocks may collapse under too-heavy fishing, and the catches may drop to a low level or even zero. Between 1960 and 1983, tuna and Alaskan pollack catches substantially increased. Peruvian anchovy catches, however, declined dramatically during this period as fishing pressures became excessive. (See Table 9.2.)

**Table 9.1 Nominal Annual Fisheries Catches, 1950–83**
*(millions of metric tons)*

| | 1950–54[a] | 1955–59 | 1960–64 | 1965–69 | 1970–74 | 1975–79 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|
| North Atlantic | 9.2 | 10.2 | 11.2 | 14.3 | 15.3 | 15.5 | 14.0 | 14.5 | 13.6 | 13.8 |
| Central Atlantic | 2.0 | 2.3 | 3.1 | 3.9 | 5.9 | 6.4 | 6.9 | 6.8 | 7.2 | 7.3 |
| South Atlantic | 0.9 | 1.2 | 1.9 | 3.5 | 3.7 | 3.9 | 3.4 | 3.6 | 3.9 | 4.0 |
| North Pacific[b] | 2.8 | 3.5 | 4.7 | 13.2 | 17.9 | 20.0 | 20.7 | 21.9 | 22.6 | 23.6 |
| Central Pacific[b] | 5.1 | 7.7 | 10.2 | 4.0 | 6.1 | 7.1 | 7.9 | 8.5 | 8.2 | 7.8 |
| South Pacific | 0.3 | 1.2 | 7.2 | 13.3 | 8.2 | 5.7 | 6.6 | 7.2 | 8.3 | 6.6 |
| Indian Ocean | 1.2 | 1.4 | 1.7 | 2.6 | 2.8 | 3.3 | 3.6 | 3.6 | 3.7 | 4.0 |
| Antarctic | NA | NA | NA | NA | 0.1 | 0.3 | 0.6 | 6.0 | 0.7 | 0.4 |
| Total Marine | 21.6 | 27.7 | 40.0 | 51.6 | 60.0 | 63.7 | 64.4 | 66.7 | 68.0 | 67.7 |
| Inland | 3.1 | 4.5 | 6.2 | 7.9 | 7.9 | 7.4 | 7.6 | 8.2 | 8.4 | 8.9 |
| **World Total** | **24.7** | **32.2** | **46.2** | **59.5** | **67.9** | **72.1** | **72.0** | **74.9** | **76.4** | **76.6** |

NA = not applicable
**Notes:**
a. Data for 1950–79 are five-year averages.
b. The division between Central Pacific and North Pacific was shifted northward after 1965.
**Source:** U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics: Catches and Landings*, for relevant years.

## FISH CONSUMPTION AND TRADE

Compared with the gross production from agriculture, the contribution of marine fish to human intake of animal protein is quite small. However, as noted earlier, it can be very important locally, particularly for people in coastal developing countries. People in some developed countries, such as Japan and Iceland, also rely on fish for an important part of their daily diet.

Not all the marine fish catch goes directly onto the table. A significant proportion of the low-valued species (anchovy, sand eels, etc.), as well as the waste from processing the higher-valued species, is turned into fish meal. This is then fed to poultry or other farm animals and appears in the human dish secondhand.

Fish is an increasingly important source of foreign exchange earnings. World exports of the major fishery commodities now exceed $15 billion annually. Prices for fish and fish products range from $100 per metric ton to more than $5,000 per metric ton. Although the data are limited, it appears that in most countries fish prices have risen more rapidly than the prices of other foods (3).

The rise in prices partially reflects changes in fish packaging. During the 1950s, about half the world catch was consumed fresh and only 1 percent was frozen (4). Today, frozen fish for human consumption comprises 22 percent of the total catch, but the amount marketed fresh has fallen to 20 percent. The share of canned fish has increased from 6 percent in the 1950s to 13 percent in 1982. Cured fish (sundried, salted, pickled, or smoked) has dropped from 33 percent of the world catch in 1951 to just 14 percent in 1982 (5). The rest of the catch, some 31 percent, is used for other purposes such as fish meal for poultry or for manufacturing soap, pharmaceuticals, etc.

Fish prices and trade are also influenced by consumption patterns. Fish use for human consumption and industrial purposes grew rapidly from 1960 to 1970. After 1970, human consumption continued to grow, and the production of fish meal declined slightly from its 1970 peak (6). Most of the growth in human consumption occurred in developing nations.

An analysis of catches by economic groupings reveals that while developed countries still harvest more than half the world catch, there has been a steady upward trend in the harvests of developing countries, especially those in Asia. Developing countries collectively increased their annual fish harvests by 3.5 percent from 1977–81 while developed countries' harvests grew a modest 0.7 percent. Five of the top ten fish-producing nations in 1982 were developing countries. (See Table 9.3.)

Developed countries dominate international trade in fish and fish products, but developing countries are taking a larger share of this trade. Between 1974 and 1982, the volume of exports of fish and fish products from developing countries doubled, and their value tripled. The Republic of Korea, Mexico, Thailand, India, Chile, and Argentina are among the countries with the most significant increases in fish exports (7). (See Table 9.4 for data

**Table 9.2 Catches of Selected Species and Species Groups, 1960–83**
*(millions of metric tons)*

| | 1960–64 | 1965–69 | 1970–74 | 1975–79 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| Salmon, Trout, Smelts, etc. | 0.4 | 0.4 | 0.4 | 0.5 | 0.6 | 0.7 | 0.6 | 0.7 |
| Tunas, Bonitos, Billfishes, etc. | 1.1 | 1.3 | 1.7 | 1.8 | 2.6 | 2.6 | 2.7 | 2.8 |
| Mackerels, Snoeks, Cutlassfishes, etc. (*Scomber* spp) | 1.7 | 1.9 | 2.6 | 3.6 | 3.3 | 3.1 | 2.5 | 2.2 |
| Jacks, Mullets, Sauries, etc. (Trachurus) | 1.1 | 1.0 | 1.6 | 2.4 | 2.8 | 3.2 | 3.9 | 3.2 |
| Atlantic Herring | 2.8 | 3.5 | 2.0 | 1.1 | 0.9 | 1.0 | 1.0 | 1.1 |
| Sardines (Sardinops & Sardina) | 1.5 | 1.9 | 1.4 | 4.4 | 7.1 | 7.9 | 8.6 | 9.5 |
| Anchoveta (Peru only) | 6.6 | 9.8 | 9.0 | 2.2 | 0.8 | 1.6 | 1.8 | 0.1 |
| Atlantic Cod | 2.4 | 3.2 | 2.8 | 2.3 | 2.2 | 2.3 | 2.3 | 2.1 |
| Alaskan Pollack | 0.6 | 1.9 | 3.1 | 4.4 | 4.0 | 4.2 | 4.5 | 5.0 |
| **Total Marine Finfish** | **34.5** | **47.2** | **52.5** | **56.0** | **56.2** | **58.4** | **59.2** | **58.8** |
| Shrimp, Prawns, etc. | 0.6 | 0.8 | 1.1 | 1.4 | 1.7 | 1.6 | 1.7 | 1.8 |
| Squid, Cuttlefishes, Octopuses, etc. | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.4 | 1.6 | 1.6 |

**Note:** Data for 1950-79 are five-year averages.
**Source:** U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics*, for relevant years.

**Table 9.3 Ten Countries with Largest Fish Production, 1982**

| Country | 1978 | 1979 | 1980 | 1981 | 1982 | 1981–82 % change |
|---|---|---|---|---|---|---|
| | (thousands of metric tons) | | | | | |
| Japan | 10,184 | 9,945 | 10,426 | 10,657 | 10,760 | 1.0 |
| USSR | 8,915 | 9,050 | 9,476 | 9,546 | 9,450 | −1.0 |
| United States | 3,418 | 3,511 | 3,635 | 3,767 | 3,922 | 4.1 |
| Chile | 1,929 | 2,632 | 2,815 | 3,393 | 3,673 | 8.3 |
| Peru | 3,473 | 3,715 | 2,735 | 2,740 | 3,452 | 26.0 |
| Norway | 2,593 | 2,658 | 2,409 | 2,539 | 2,463 | −3.0 |
| India | 2,306 | 2,340 | 2,438 | 2,415 | 2,400 | −0.6 |
| Korea, Republic of | 2,092 | 2,162 | 2,091 | 2,366 | 2,281 | −3.6 |
| Indonesia | 1,642 | 1,742 | 1,842 | 1,903 | 2,020 | 6.1 |
| Denmark | 1,740 | 1,738 | 2,026 | 1,852 | 1,907 | 3.0 |

**Source:** U.N. Food and Agriculture Organization (FAO), *INFOFISH Marketing Digest*, No. 5 (FAO, Rome, 1983), p. 1.

on the ten largest fish exporting and importing countries from 1974–82.)

## FOCUS ON: THE IMPACTS OF THE NEW LAW OF THE SEA ON FISHERIES

By the end of 1985, 159 countries had signed the 1982 United Nations Convention on the Law of the Sea. Although the United States and several other major countries have not signed the treaty, the concept of a 200-mile Exclusive Economic Zone (EEZ) is already effectively in operation. This legal concept is a particularly significant one for fisheries, since it recognizes that coastal states have sovereign rights over all fishing (including that by foreign vessels) within 200 miles of their coasts. Foreign ships may be allowed access to fish in this zone when the potential harvest is greater than the amount harvested by the coastal nation. The definition of potential harvest is sufficiently vague, however, that coastal states can reasonably claim this quantity as the sum of their own catches plus the amount allowed to foreigners. (See Part IV, Chapter 10, "Oceans and Coasts.")

Many people expected that the 1982 Law of the Sea Convention would result in major changes in world fisheries. Some thought it would allow developing countries to take a larger share of the world catch—at the expense of fleets from rich, developed countries. Others feared that the total amount of fish caught might drop significantly because coastal states would not have the immediate capacity to replace foreign fishing vessels.

Neither expectation has been fulfilled. Since the bulk of distant water fishing was off the coasts of the developed world, these countries gained most in terms of control over fishery resources. The United States and Canada were the biggest gainers; others included Australia, New Zealand, South Africa, and many countries of northwestern Europe (8). Nevertheless, some developing countries, particularly the South Pacific island nations and some west African countries have also acquired legal control over valuable fisheries through the EEZ concept. Nor did the new legal regime lead to large short-term declines in total catch, because the developing coastal countries have allowed foreign fishing to continue, albeit under conditions that provide some benefits to the coastal country. These controls may determine the amount that can be caught, license fees, and the proportion of the catch that must be landed for local processing.

The catch trends in the years after the changes in jurisdiction have deviated from the predictions in different ways. In the Southeast Atlantic the share of non-local vessels remains high. Coastal states in this region have not benefited much because they lack enforcement capability. Most of the region's non-local catch is taken off the coast of Namibia, which suffers from both a lack of enforcement capacity and a government that is not generally recognized. Since the collapse in 1974 of the pilchard stock, which had been one of the mainstays of the local fishery, the share of non-local fishing has actually increased.

In the Northwest Atlantic fishing region, the long-range and total catches dropped substantially (9). This drop, however, was primarily due to overfishing that occurred prior to enactment of the new Exclusive Economic Zone provision rather than to the provision itself (10). The United States and Canada prohibited most foreign fishing in the area, which reduced fishing pressure on some of the more heavily-fished stocks. Domestic fishing still exerts moderate to heavy pressure, however, making recovery a slow process (11).

In two other areas, the Eastern Central Atlantic (off northwest Africa) and the Northeast Pacific (the Bering Sea and the Gulf of Alaska), the coastal countries have allowed foreign fishing to continue. The countries of northwest Africa do not currently have the capacity to replace a large reduction in foreign fishing. Generally speaking, there has been no need to reduce fishing to conserve stock. Overall, therefore, the total catch in these

**Table 9.4 Ten Largest Exporters and Importers of Fish, 1982**

| Exporters | 1981 | 1982 | 1981–82 Percent Change | Importers | 1981 | 1982 | 1981–82 Percent Change |
|---|---|---|---|---|---|---|---|
| | (millions of dollars) | | | | (millions of dollars) | | |
| 1. Canada | 1,267 | 1,291 | + 2 | 1. Japan | 3,737 | 3,998 | + 7 |
| 2. United States | 1,142 | 1,034 | − 9 | 2. United States | 2,988 | 3,226 | + 8 |
| 3. Denmark | 940 | 901 | − 4 | 3. France | 1,051 | 1,056 | NC |
| 4. Norway | 1,002 | 888 | −11 | 4. United Kingdom | 995 | 886 | −11 |
| 5. Japan | 863 | 807 | − 7 | 5. Germany, Federal Republic of | 819 | 819 | NC |
| 6. Korea, Republic of | 835 | 759 | −11 | 6. Italy | 720 | 755 | + 5 |
| 7. Mexico | 538 | 620 | +15 | 7. Spain | 479 | 466 | − 3 |
| 8. Iceland | 713 | 536 | −25 | 8. Hong Kong | 362 | 467 | +29 |
| 9. Netherlands | 512 | 504 | − 2 | 9. Nigeria | 520 | 400 | −23 |
| 10. Chile | 365 | 408 | +12 | 10. Belgium | 348 | 327 | − 6 |
| **Total** | **8,177** | **7,748** | **− 5** | **Total** | **12,019** | **12,400** | **+ 3** |
| **Percent of World Total** | **53** | **50** | | **Percent of World Total** | **74** | **75** | |

NC = no change
**Source:** U.N. Food and Agriculture Organization (FAO), *Fishery Commodity Situation and Outlook* (FAO, Rome, 1983), p. 12.

## Box 9.1 Regional Fish Harvest Trends

Fluctuations in regional catches have been much greater than changes in the total world catch. In some areas, such as the Western Central Atlantic, fish stocks that had been largely ignored or only lightly fished are being increasingly exploited. In others, such as the upwelling areas off Peru and off Southwest Africa, there have been major changes in the distribution and abundance of the fish stocks themselves.

The West Central Atlantic borders on North, Central, and South America. Catches in this region have been increasing annually since 1973 primarily because of increased fishing by Mexico (1). The United States, Cuba, Venezuela, and Brazil also exploit this region's resources extensively. The most important commercial fisheries are those for shrimp; these stocks are fully exploited and have changed little in the past decade. In terms of weight, however, the fish—especially pelagic fish such as menhaden—are more important. These stocks have been fished less heavily, and catches of some species are increasing significantly.

There has also been a large increase in the reported catches of anchovy in the Black Sea—though some of this may be due to improved statistical reporting, rather than bigger catches. In addition, the catches from the Mediterranean—where most stocks, especially around the European coasts, are fully exploited—have increased by 50 percent in the past decade.

The Southwest Atlantic offers the greatest opportunity for expanded fishery operations. Total catches in this region increased from 1.3 million metric tons in 1981 to 1.7 million metric tons in 1983. Larger catches of southern blue whiting and squid are primarily responsible for the increase (2). In this area, Polish fleets catch most of the southern blue whiting—a species that was virtually unexploited a few years ago. There is serious concern, however, that the stock will soon be overfished if the current rate of growth in the harvest continues. Polish, Japanese, Soviet, and Argentinian fleets catch the majority of squid in the Southwest Atlantic region. Squid harvests amounted to 200,000 metric tons in 1983 (3).

The abundance of red shrimp in the Southwest Atlantic has captured the interest of the world's fishing fleets. As a result, catches of red shrimp have been rising steadily: from 2,600 metric tons in 1981 to 19,000 metric tons in 1983 (4).

The biggest fishery in the Southwest Atlantic is still hake, exploited almost entirely by Argentinian and Uruguayan fleets. Catches of hake have been stable since 1980, and the species seems to be moderately exploited (5).

Changes in global meteorological conditions have a marked effect on the strength and direction of ocean currents, which in turn affect the distribution and migration patterns of fish. The unusual meteorologial conditions that arose in 1983 over the Pacific generated El Niño, a strong warm current off the west coast of South America that can extend across the Pacific as far as Indonesia. During that year the surface waters were unusually warm and this is thought to be the main cause of the dramatic reduction in the total catch from the South Pacific. Fisheries off the coast of Ecuador were most seriously affected; the mackerel migrated south, away from Ecuadorian fishing grounds and catches fell precipitously, from 700,000 metric tons in 1981 to 134,000 metric tons in 1983 (6).

Similar reductions have occurred in the Southeast Atlantic. Pilchard stocks off both South Africa and Namibia have been severely reduced by heavy local fishing. While there has been an increase in the abundance of horse mackerel, fished mainly by the long-range fleets from Eastern Europe, it has not been sufficient to prevent a decline in the area's total catch since the early 1970s. All the major stocks in the region—hake, horse mackerel, and anchovy—are now heavily fished. Unless the pilchard stocks recover, which they show no signs of doing, total catches from this region are unlikely to increase.

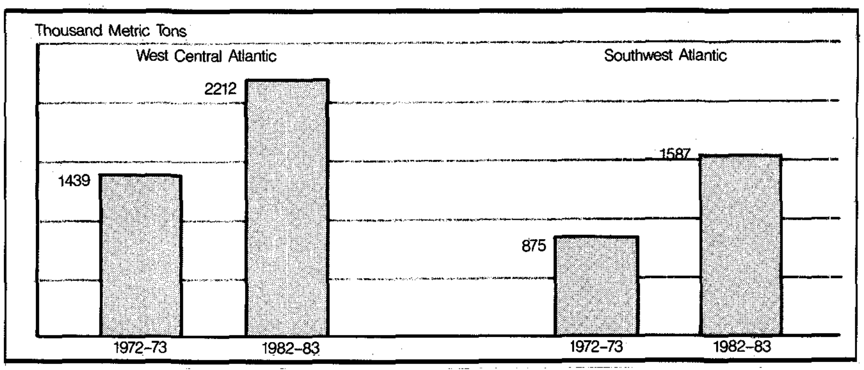
The most striking increase in a fishery catch has been that of the Japanese sardine, whose catches topped 4 million tons in 1983, compared with only 9,000 tons in 1965. This species has been the main contributor to the continued rise in catch totals from this region, currently some 21 million tons. Other important species in this region are Alaskan pollack, mackerel, squid, and a variety of demersal fish. Most of these and other species are heavily fished, though the potential exists for some increase in the production of squid from the off-shore regions.

On both sides of the Pacific the recent trends in salmon catches have been encouraging. All species of salmon had been severely reduced by heavy fishing, combined with the effects of pollution and environmental degradation in their spawning streams. Recent controls on the amount of fishing, both in the open ocean and in home waters, along with some improvements in river conditions and active re-stocking programs, have led to an upward trend in total catches.

### References and Notes


1. U.N. Food and Agriculture Organization (FAO), *Review of the State of World Fishery Resources* (FAO, Fish Circular 710, Revision 4, 1985), p. 10.
2. *Ibid*, p. 14.
3. *Op. cit.* 1, p. 15.
4. *Op. cit.* 1, p. 14.
5. *Op. cit.* 1, p. 16.
6. *Op. cit.* 1, p. 27.


**Figure 1 Annual Fish Catch in Two Fishery Regions, 1972–83**




**Source:** U.N. Food and Agriculture Organization. See Part IV "Oceans and Coasts," Table 10.2.

areas has remained unchanged. Domestic fishing has slowly increased, however, while foreign fishing has fallen slightly (12,13).

Similar patterns are apparent in most other areas—for example, around Australia and New Zealand, and off Argentina—where long-range fishing was significant. Where local capacity can replace foreign ships, it has largely done so, but elsewhere much foreign fishing remains (14).

Only a few developing countries have realized significant immediate gains from the changes in international ocean law. Many of these gains have come from economic cooperation with countries operating long-distance fleets. Cooperation often takes the form of joint ventures; the foreign nation usually provides the vessels, capital, technical know-how, and in some cases the markets, while the coastal country supplies access to the resource and the less skilled labor. Often arrangements are made so that as local people gain experience on foreign fleets, they assume more senior positions. Eventually the fishery becomes a coastal country's operation, supplying foreign markets.

Although the new legal regime may appear not to have made a significant impact on fisheries, it may yet play a key role in the management of the ocean's resources. Before the new law, the bulk of the marine fish catch was taken beyond recognized national jurisdiction, which varied from 3 to 12 miles. Management measures could be introduced only through international agreements entered into voluntarily by the countries concerned, and these measures were largely ineffective because they were based on the lowest common denominator. About 99 percent of the world catch is now taken in water that is already, or potentially, under the jurisdiction of a coastal country (15). The road to better management, therefore, is now open.

## Marine Fisheries Potential

Various estimates have been made of how much fish can be taken from the sea. Estimates sometimes differ markedly, often because of differences in definitions—for example, technical potential versus economic potential, or conventional resource potential versus a combination of conventional and unconventional resource potential.

The most generally accepted estimates of *conventional resource potential* are on the order of 100 million metric tons (16). This figure includes the types of fish sold in fish markets or used for fish meal plus all other species of roughly similar characteristics. It is highly unlikely that the actual catches will ever approach this potential figure. Some stocks, for example the demersal fish in the deeper parts of the continental shelf in many tropical areas, though marketable, are scattered. With present technology, it is unlikely that sufficient quantities can be caught at a cost that is economically worthwhile. There are still some opportunities for increased catches (e.g., the demersal stocks off the northwest coast of Australia), but they are becoming increasingly limited.

Moreover, this estimate of potential assumes that each stock is exploited at its optimum level. Where several species live together and are vulnerable to the same fishing operations, it is not possible to fish each stock optimally; some are bound to be underexploited and others overexploited.

In practice, matters are often worse. Though fish stocks have proved remarkably robust in the face of uncontrolled exploitation, several have collapsed. Rebuilding these stocks (e.g., the Peruvian anchovy and the pilchard off Namibia), as well as maintaining the productivity of the stocks that provide a yield near the optimum, are essential if the world catch is to increase significantly, and to approach even 80–90 million metric tons.

Estimates of potential yield are higher if *unconventional resources* are also included. It is more difficult to give precise figures for economically feasible potential, however, because the quantity to be harvested depends on changes in consumer tastes and because the economics of harvesting these resources may change with improved technology. The best known unconventional resources are the krill in the Antarctic, several species of oceanic squid, and the lantern fish and other small fish in the upper parts of the deep oceans. Krill has attracted the most attention.

Krill certainly exist in large numbers. Estimates of theoretical potential yield vary greatly, but even the most conservative figures run into tens of millions of metric tons. Krill can be caught in large quantities—several tons per hour with a midwater trawl—but despite the region's low temperatures, their quality deteriorates rapidly, and processing must be rapid. This factor, combined with the bad weather of the Southern Ocean and the long distances from any base, makes a large proportion of the resource economically unattractive at present.

The total krill catch, taken mostly by the Soviet Union and Japan, increased rapidly between 1974 and 1980, reaching nearly half a million metric tons in the 1979–80 and 1980–81 seasons, and topping that figure in 1981–82. The catch then fell to some 220,000 metric tons in 1982–83, largely because of reduced fishing by the Soviet Union (17). The demand for krill in Japan is currently quite small—a few tens of thousands of metric tons. The falling Soviet catch suggests problems in disposing of the larger quantities. Thus, significant increases in the krill catch seem unlikely unless there is a major processing or marketing breakthrough.

The situation for the other unconventional resources is similar. The resources exist: for example, good catches have been taken by research vessels in the Arabian Sea, which seems particularly rich in meso-pelagic fish. The cost of fishing, however, still exceeds the likely return on any market (e.g., for fish meal) that would seem capable of absorbing large quantities. Really large-scale exploitation of meso-pelagic fish or oceanic squid seems at least as far off as a krill fishery.

Aquaculture is sometimes seen as a means of vastly increasing the total marine fish yield worldwide because it can produce much higher yields per unit of area than fishing can. A major constraint on total aquaculture production, however, is that most of the products that people want are high on the food chain, and therefore, are expensive to produce. Also, marine fish move over large areas, making it difficult to rear them in enclosures.

Mollusks are immobile after the first few days or weeks of life and in that sense are easy to culture, provided they grow large enough to be commercially attractive. Notable centers of mollusk culture are or have been western Europe (Holland and Spain for mussels, France for oysters), the United States (Chesapeake Bay for oysters), and Japan. Overall mollusks are a strong branch of aquaculture.

Shrimp, milkfish, and a few other species are also well suited to aquaculture. They are low enough on the food chain to provide reasonable yields per unit area; yet they are valuable enough to make the operation worthwhile. Where conditions are favorable (for example, Ecuador and Southeast Asia), shrimp culture in lagoons and similar areas is currently among the fastest growing fishery businesses. However, it has also been one of the major causes of mangrove degradation in these areas. (See "Mangroves," below.)

Aquaculture does offer further opportunities for increasing the marine fisheries harvest, but it will be restricted to very small areas.

## FUTURE PROSPECTS

The outlook for marine fisheries is not bright. The factors that have caused recent problems—limited resources and excessive exploitation of these resources—are likely to continue. Although an increase in total catch can be expected from those stocks of conventional fish that are not fully exploited, the economic obstacles to large scale harvesting of krill and meso-pelagic fish are likely to remain for the immediate future. Some depleted stocks, especially herring off Norway and in the North Sea, are recovering, but neither the scientific knowledge nor the political will to prevent the collapse of similar stocks is certain. Fisheries that may be at risk include the sardines off northwest Africa (whose geographical range seems to have shrunk recently) and the oil-sardines off the west coast of India (which have periodically been scarce) (18).

By acquiring jurisdiction over the resources in a wide zone off their coasts, coastal nations have an opportunity to improve management by matching productivity of the resources with the fishing capacity used in harvesting them. Some countries have grasped this opportunity, and a few—like the United States, with its Fishery Conservation and Management Act of 1976—have combined extension of jurisdiction with a fundamental reexamination of how the resources in the new Exclusive Economic Zone should be conserved and utilized.

But overall, the problems have not been recognized. As long as a world fishery conference at the highest policymaking level has as one of its major recommendations a call for more investment in fisheries without strict reservations on how and where that investment is applied, the problem will remain. (See "Recent Developments," below.) Overcapacity will remain a threat to many resources, especially those such as herring and sardines, which seem particularly susceptible to overfishing. It will also be a major cause of conflict and reduced prosperity among fishermen, especially the small-scale fishermen of developing countries.

## COASTAL ECOSYSTEMS

The coastal zone represents the transition from terrestrial to marine influences and vice versa. It comprises not only shoreline ecosystems but also the upland watersheds draining into coastal waters, and the nearshore sub-littoral ecosystems influenced by land-based activities. Extending several hundred kilometers seaward, the coastal zone includes offshore banks and continental shelves. Coastal waters include the major upwelling areas of the world—such as those off the coasts of Peru and the western coasts of North America and Africa—where highly productive waters support major fisheries. Functionally, it is a broad interface between land and sea that is strongly influenced by both.

Although nearshore coastal waters are a very small part of the oceans, they are often sheltered areas of high localized productivity, based primarily on the concentration and cycling of nutrients from adjacent land masses. Among their most important characteristics are the intimate links between neighboring communities, which render the whole complex more diverse and productive than any of its constituent parts. Coastal ecosystems and adjacent oceanic production are interconnected in terms of energy flow and subsidies, nutrient and mineral cycling, the movement of water and organisms, and the requirements for species of economic and/or ecological importance in one system to complete portions of their life cycles in other systems. The highly productive fisheries in the Java seas, for example, may be attributed to the increased primary productivity in ocean waters that are fed by estuarine flooding from freshwater runoff into coastal waters (19).

Coastal ecosystems play a major role in the life cycles of economically important finfish and shellfish species by providing feeding, breeding, and nursery habitat. For example, an estimated 98 percent of all fish caught in the Gulf of Mexico are estuarine dependent (20), and juvenile lobsters occupying seagrass beds are the source for a coral reef fishery that provides Belize with over 80 percent of the income from its second largest foreign exchange earning industry (21). Further, exports are only a fraction of the total catch that provides food for the majority of coastal nations' residents. Tropical Pacific islanders depend upon coastal marine resources for at least 90 percent of their protein intake (22).

Additional functions of coastal ecosystems include the critical role of buffering the joining of land to sea by moderating coastal erosion and large salinity changes. Coral reefs, for example, act as barriers dissipating wave and current energy, and mangroves, by occluding and absorbing terrestrial freshwater runoff, buffer salinity changes in coastal waters.

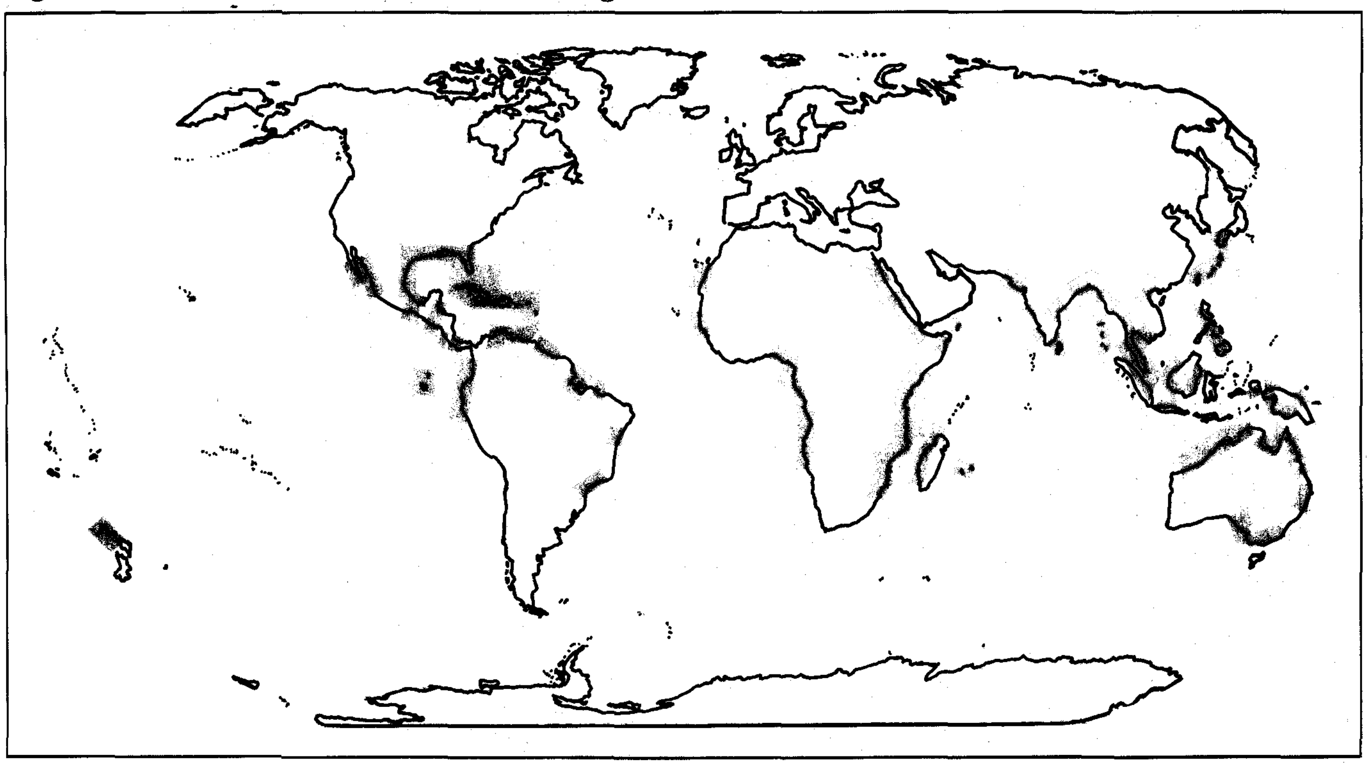
Many of the most biologically productive coastal communities are in tropical regions, where they are threatened by population and development pressures. (An estimated two thirds of the world's human population resides along coastlines and banks of rivers draining into coastal waters (23).) This section focuses on the three major resources of the coastal tropics—mangroves, seagrass beds, and coral reefs.

### Mangroves

As much as 75 percent of low-lying tropical coastlines with freshwater drainage are dominated by salt-tolerant trees or shrubs known as mangroves (24). (See Figure 9.1.) There are some 240,000 square kilometers of mangrove-dominated intertidal, lagoonal, and riverine flatlands with mangrove forests reaching their greatest extent along the coasts of South and Southeast Asia, Africa, and South America (25).

Mangrove forests are one of the most productive and biologically diverse ecosystems in the world, providing habitat for more than 2,000 species of fish, invertebrates, and epiphytic plants (i.e., those that live on the surface of other plants, deriving support but not nutrients from their "host" plants) (26). Nutrients released through the decomposition of the abundant mangrove leaf and twig litter are an important direct and indirect food source for aquatic animals, including economically important fisheries species. This litter can be the first link in a long food chain terminating with open-ocean fisheries. For

**Figure 9.1 Distribution of the World's Mangroves**



**Source:** Snedaker and Getter, 1985, Reference 25.

example, shrimp abundance in offshore waters increases with the size of the mangrove tidal forest nursery grounds (27). In Fiji, about half the commercial and artisanal fisheries use mangrove areas for at least one critical stage in their life cycles, and at least 83 percent of the mangrove-dependent fish species harvested are used for food (28). In eastern Australia, 67 percent of the entire commercial catch is composed of species that depend on mangrove estuarine areas, and an estimated 80 percent of all marine species of commercial or recreational value in Florida depend on mangroves for some stage of their life history (29).

Mangroves are also valuable as a source of timber, pulpwood and chips, fuel, and charcoal (30). In addition, their extensive root systems act as silt traps, stabilize shorelines, and help maintain estuarine and coastal water quality (31,32). Thailand and the United States are among the countries that deliberately cultivate mangroves to prevent shore erosion (33).

Although key pressures on mangrove ecosystems vary from country to country, by far the greatest threats are clear-cutting, diversion of freshwater from upland watersheds, and reclamation for agriculture and aquaculture (34). One major consequence of such mangrove degradation is reduced fish yields. Table 9.5 presents a preliminary list of key threats to mangroves and the regions where these threats are of greatest concern. Brackish water aquaculture has a particularly pronounced environmental impact because of the fundamental changes it creates in the mangrove environment.

In Southeast Asia, mangrove ecosystems are frequently converted to brackish water fish ponds for the culture of prawns and milkfish. In the Philippines, for example, aquaculture production—which approximately doubled between 1952 and 1977—was responsible for an estimated four fifths of the mangrove destruction that took place there between 1967 and 1977 (35,36). Similarly, in the Gulf of Guayaquil, Ecuador, an estimated 16 percent of the mangrove swamps were reclaimed for shrimp production between 1966 and 1982, with more than half the decline in mangrove area occurring between 1977 and 1982 (37). At present rates of decline, mangroves could disappear from both these areas by the mid-1990s.

In the Gambia, a proposed dam on the Gambia River is likely to reduce the existing mangrove area by about 70 percent (38). The mangrove food chain presently supports 40 percent of the total fish catch for the Gambia River estuary (39); assuming a 70 percent mangrove decline, the 40 percent would be reduced to about 12 percent. Additional examples of trends in the extent of mangroves are given in Figure 9.2 for selected countries where data are available. There are no global systematic quantitative estimates of mangroves, seagrass beds, and coral reefs destroyed or degraded over the last 10–20 years.

An awareness of the value of mangrove swamps for forestry, fisheries, and recreation has prompted several initiatives to protect mangrove ecosystems. Currently, the total area of mangrove forests under some degree of preservation represents less than 1 percent of the entire

## Table 9.5 Major Causes of Recent Degradation of Mangrove Ecosystems By Region

| | Indo-Pacific | South Asia | Southeast Asia | Africa | Central America | South America | Wider Caribbean |
|---|---|---|---|---|---|---|---|
| Clear-cutting | + | + | + | + | + | + | + |
| Firewood | + | + | + | + | + | + | + |
| Freshwater Diversion | | + | | + | | | |
| Land Reclamation: | | | | | | | |
| Agriculture | + | + | + | + | | | + |
| Aquaculture | | + | + | + | + | + | + |
| Development: | | | | | | | |
| Urban | + | + | + | + | | + | + |
| Industry | + | | + | + | | | |
| Ports | + | + | + | + | | + | + |
| Siltation from Land Runoff | + | | | + | | | |
| Mining | + | | + | | | | |
| Solar Salt | + | + | | + | + | | + |
| Pollutants: | | | | | | | |
| Chemical | + | | + | + | | | + |
| Domestic | + | | + | + | | | + |
| Oil | + | | + | | | | + |
| Tourism/Recreation | + | | | + | | | + |

**Sources:**
1. N.L. Berwick, "Guidelines for the Analysis of Biophysical Impacts to Tropical Coastal Marine Resources," in *Proceedings of the Bombay Natural History Society Centenary Seminar: Conservation in Developing Countries—Problems and Prospects*, December 1983 (Bombay, India, in press, 1985).
2. Hamilton and Snedaker, 1984, Reference 26.
3. H.T. Odum *et al.*, *The Ecology of Mangroves of South Florida: A Community Profile* (U.S. Department of the Interior, Washington, D.C., 1982).
4. P. Saenger, *et al.*, Eds., *Global Status of Mangrove Ecosystems*, Commission on Ecology Papers, No. 3, (International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, 1983).

resource. At least 18 countries have preserves that are intended to give absolute protection to mangrove ecosystems or to enhance the survival of particular species within these ecosystems. If one also includes reserves where controlled access and use are permitted for forestry, fisheries, or recreation, the number of countries with protected mangroves doubles. Yet few of these reserves are adequately managed (40).

### Seagrasses

Seagrasses are salt-tolerant plants similar in appearance to their terrestrial counterparts, but they grow under water. Seagrass communities are widely distributed throughout much of the temperate and tropical coastal environments of the world, where they thrive in clear, calm, and shallow waters. (See Figure 9.3.) Tropical seagrasses are concentrated in the Indo-West Pacific and the Caribbean.

Seagrass communities are known for their ability to trap and bind sediment, thus retarding erosion of shallow water sediments. The buffering effect of seagrasses assumes additional importance in reducing turbidity and clarifying the surrounding waters, an effect beneficial not only to the seagrasses themselves but also to associated filter-feeding invertebrate communities and nearby coral reefs.

Seagrasses provide a habitat for fish and other marine organisms. They are also a source of food materials, consisting mostly of epiphytes (predominately algae) that live on the leaf surfaces and macrofauna that abound among seagrasses and in the rich layer of detritus. The primary commercial value of seagrass beds, in fact, derives from their importance as forage and critical habitat for fisheries species as well as some of their food sources. Postlarval stages of commercially important fisheries (e.g., tiger prawns in eastern Queensland, Australia) concentrate and develop in these areas (41). Seagrass beds also provide spawning grounds for adult breeding populations of fisheries species (42). It has been estimated that one hectare of seagrass in the Arabian Gulf can contribute an annual yield of as much as 850 kilograms of shrimp, a valued source of foreign exchange in many countries (43).

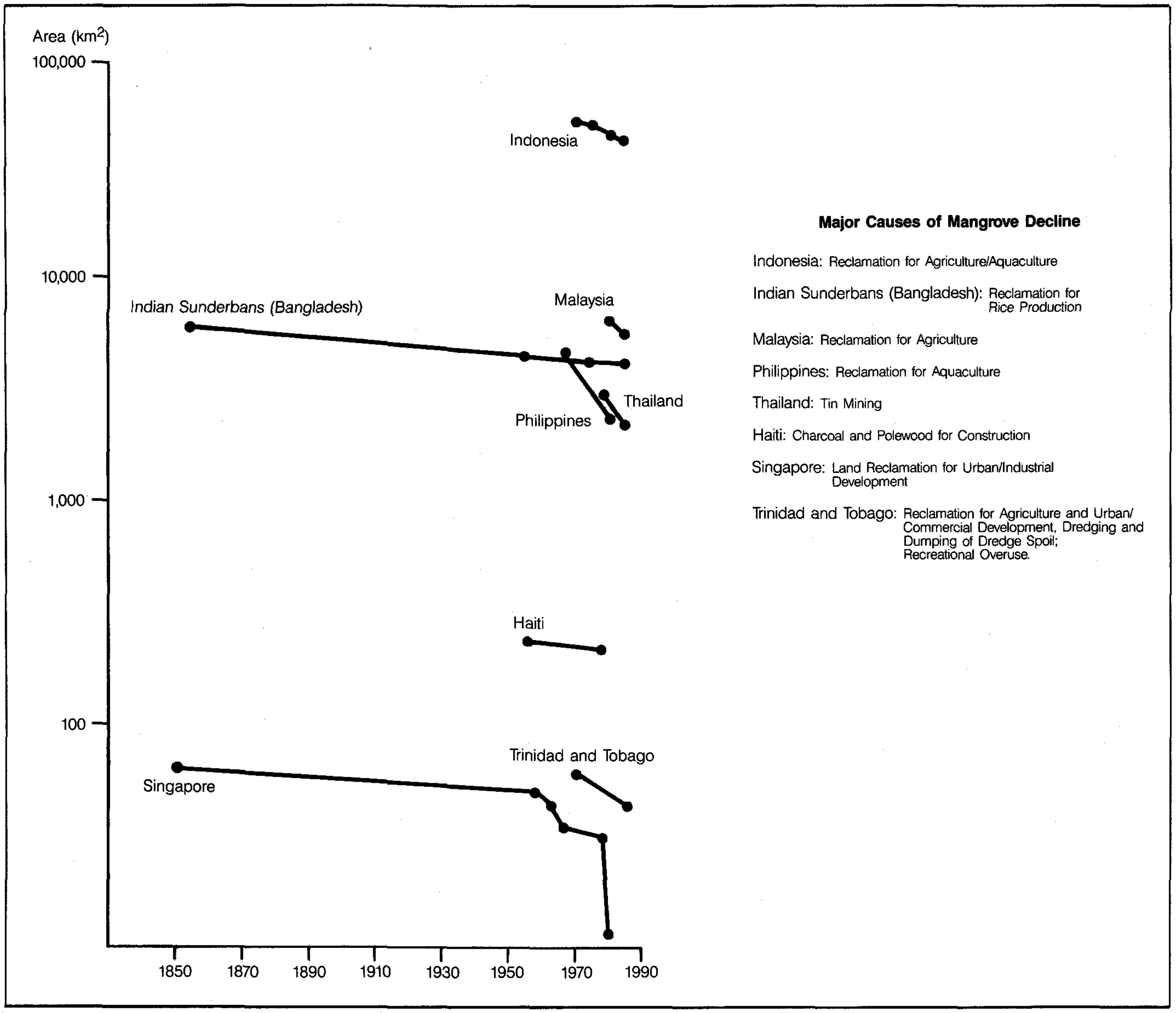
Seagrasses intermingle with both mangrove and reef communities at their respective seaward and landward boundaries. Extensive submarine meadows frequently provide the link between the environmentally different mangrove and coral reef ecotypes. The migration of animals at various life stages from one ecosystem to another for feeding and shelter, coupled with the flow of water that transports both organic and inorganic material from runoff and tidal flushing, ties the offshore coral reefs to nearshore seagrass beds, and the seagrass beds to mangrove estuaries (44).

The major threats to seagrasses are dredge and fill operations, fishing practices that use bottom trawls, and water pollution such as that caused by industrial wastes, thermal discharges from power plants, and accidental spills of petroleum products (45). (See Table 9.6.) Because baseline information on the global extent of seagrasses has not been collected, it is difficult to assess their condition and trends. However, there are a few isolated reports of damage to seagrass communities.

Preliminary mapping of seagrass cover in Western Australia indicates that seagrass beds in Cockburn Sound were reduced by an estimated 79 percent between 1954 and 1978 (46). This loss followed industrial development along the shore and coincided with the discharge of effluents from a fertilizer factory (47). Similarly, dredge and fill operations were primarily responsible for a 65.4 percent loss of seagrasses in Princess Royal Harbor and a 41 percent loss at Oyster Harbor in Australia (48).

The loss of seagrasses decreases the quantity of marine life; one study revealed five times more fish and invertebrates residing over seagrass beds than over a mud/sand/shell habitat (49). A dredge and fill operation in Boca Ciega Bay, Florida, in the United States, destroyed 20 percent of the seagrass bed, resulting in an 80 percent reduction in the number of species, and caused an estimated $1.4 million loss in fish production (50).

**Figure 9.2** **Trends in Extent and Major Causes of Decline in Mangroves in Selected Countries, 1850–1990**




**Sources:**

For Indonesia:

1. E.D. Gomez, *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution: Philippines* (South China Sea Fisheries Development and Coordinating Programme, Manila, 1980), p. 17.
2. A. Soegiarto, *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution: Indonesia* (South China Sea Fisheries Development and Coordinating Programme, Manila, 1980), p. 1.

For Malaysia:

3. A. Sasekumar, *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution: Malaysia* (South China Fisheries Development and Coordinating Programme, Manila, 1980), p. 2.
4. National Environment Board (NEB), "Country Report: Malaysia", in *Living Resources in Coastal Areas with Emphasis on Mangrove and Coral Reef Ecosystems: Report of the Technical Meeting of ASEAN-Australia Cooperative Programs in Marine Sciences* (NEB, Bangkok, Thailand, 1984), p. 1.

For Sunderbans (Bangladesh):

5. Hamilton and Snedaker, 1984, Reference 26, p. 93.

For Philippines:

6. National Environment Protection Council, *The Philippine Environment* (Ministry of Human Settlements, Manila, 1979), p. 22, 25.
7. E.D. Gomez, *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution: Philippines* (South China Sea Fisheries Development and Coordinating Programme, Manila, 1980), p. 1.

For Thailand:

8. National Environment Board (NEB), "Country Reports: Thailand," in *Living Resources in Coastal Areas with Emphasis on Mangrove and Coral Reef Ecosystems: Report of the Technical Meeting of ASEAN — Australia Cooperative Programs in Marine Sciences* (NEB, Bangkok, Thailand, 1984), p. 1.

For Haiti:

9. E. Wilcox and J. Talbot (Eds.), *Haiti Country Environmental Profile: A Field Study* (U.S. Agency for International Development, Washington, D.C., in press, 1985), p. 133.

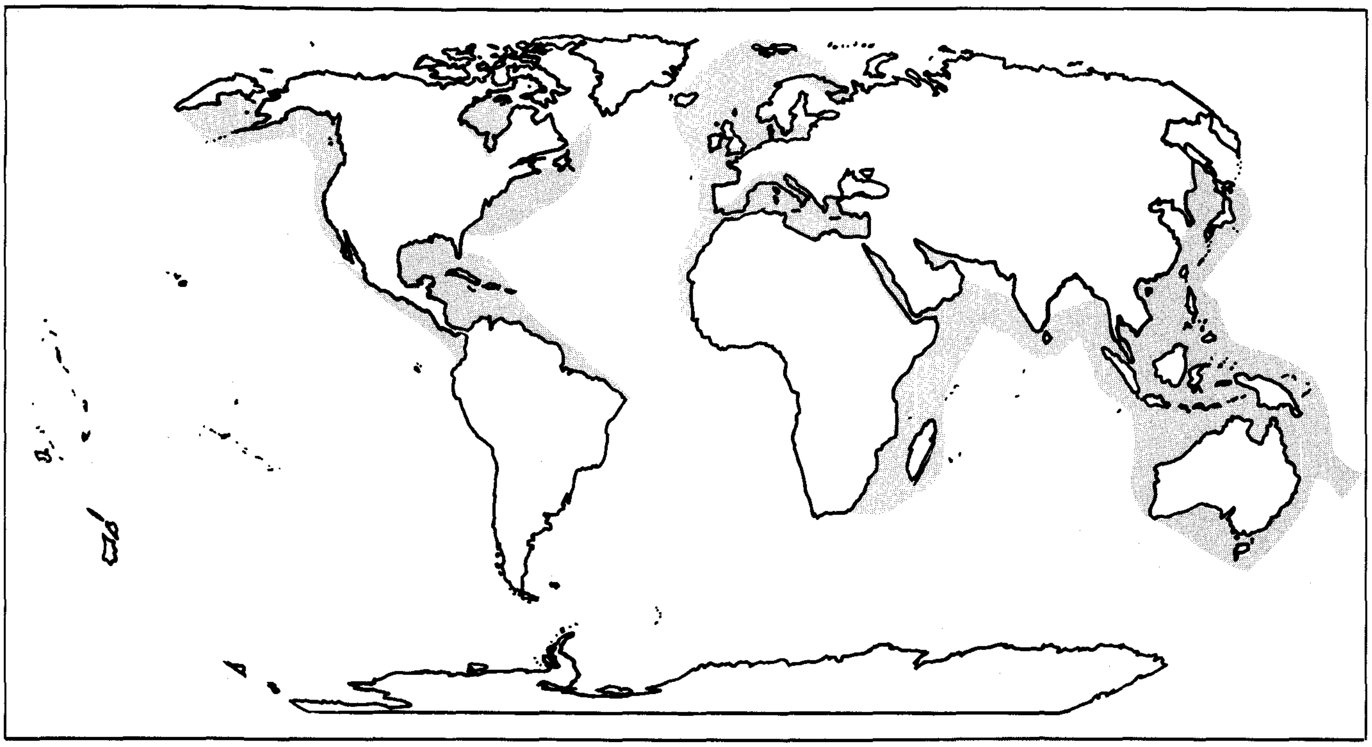
For Singapore:

10. Department of Zoology, University of Singapore, *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution: Singapore* (South China Sea Fisheries Development and Coordinating Programme, Manila, 1980), p. 3.

For Trinidad and Tobago:

11. D. Ramsaroop, Institute of Marine Affairs, Trinidad and Tobago, 1985 (personal communication).

**Figure 9.3 Distribution of the World's Seagrasses**



**Source:** G.W. Thayer and M.S. Fonseca, *The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile* (U.S. Department of the Interior, Washington D.C., 1984).

To date, no preserves have been established specifically for the protection of seagrasses, although they have sometimes benefited from adjacent habitats under protected status. Mangroves, for example, are the primary ecosystem concern of the Everglades National Park in Florida, even though seagrasses comprise about 85 percent of the submerged macro-vegetation of the coastal waters under protection. Seagrasses also dominate the Looe Key National Marine Sanctuary off the Florida coast; yet the focal point of the park is its species-rich coral reefs (51).

## Coral Reefs

Stony or reef-building corals are a dominant feature of the shallow coastal marine environment in almost all areas of the tropical circumglobal belt remote from major upwellings or inflows of freshwater. Exceptions to this pattern occur where warm currents extend beyond the tropics. (See Figure 9.4.) On a global basis, coral reefs and associated communities cover an estimated 600,000 square kilometers, with 30 percent found in the "Asiatic Mediterranean" (bounded by Indonesia to the west, northern Australia to the south, the Philippines to the east, and mainland Asia to the north). An additional 30 percent is found in the Indian Ocean, Arabian Gulf, and Red Sea, 13 percent in the South Pacific, 12 percent in the North Pacific, 14 percent in the Caribbean Sea and North Atlantic, and 1 percent in the South Atlantic (52).

Coral reefs are the marine version of tropical rainforests, rivaling their terrestrial counterparts in productivity and richness of species. The 150-kilometer-long barrier reef surrounding Palau in the Pacific, for example, has nine species of seagrasses, more than 300 species of corals, and about 2,000 species of fish (53). An estimated 80 genera and 500 coral species form the Great Barrier Reef, the longest reef system in the world, stretching over 2,000 kilometers along Australia's eastern coast (54).

Approximately one third of all fish species live on coral reefs (55). Coral reefs contribute to fisheries in three ways: fishing directly on the reef; fishing in shallow coastal waters where coral reefs are critical to food webs, life cycles, and productivity; and fishing in offshore waters where the reef's high productivity may be important regionally.

Reports of fish yields from coral reefs appear to vary widely from less than 1 metric ton per square kilometer per year to almost 20 metric tons per square kilometer per year (56). Present evidence suggests that a sustainable harvest of all edible fish, crustaceans, and mollusks averaging 15 metric tons per square kilometer per year could be derived from all coralline areas less than 30 meters deep (57). The corresponding theoretical potential harvest on a global basis amounts to 9 million metric tons per year, the equivalent of 12 percent of today's total world fish production (58).

Coral reef-dependent artisanal fisheries have been reported to account for up to 90 percent of the fish production in Indonesia (59) and up to 55 percent of the reported fish catch in the Philippines in 1975 (60). This harvest contributes to more than 54 percent of the protein intake of all Filipinos (61). The importance of such fisheries as a necessary protein supply to a distinct population of small-scale fishermen and their dependents is easily obscured when dealing with fisheries on a global or even on a national level.

Coral reefs supply food for harvestable pelagic fisheries in non-reef areas as well. For example, two of three harvested tuna species near New Caledonia are known to feed primarily on coral reef fish (62), and a Solomon Island skipjack tuna fishery operated by a Japanese enterprise depends upon reef baitfish (63). Two of the most important and relatively unappreciated functions of coral reefs are their roles in coastal protection and island building. Along the southwest coast of Sri Lanka near Hikkaduwa, coral mining for a variety of construction and industrial purposes (e.g., lime, calcium carbide, and cement production) has caused serious coastal erosion (64). Concentrated exploitation of the offshore coral reefs has accelerated erosion along a six-mile stretch of coastline, from which an estimated 75,000 tons of coral are mined annually (65). As a result, the "beach" has moved 300 meters inland from its original position, whittled away by direct wave action over a 50-year period (66).

With regard to island building—even though the principal island type consists of granitic bedrock—77 percent of the *isolated islands* and *island archipelagos* in the Indian Ocean are built exclusively from reef deposits (67). The entire Maldive Archipelago, comprising 20 atolls and an estimated 2,000 coral islands, would not exist were it not for coral reefs. Without coral reefs the Seychelles would not have 47 percent of their total land area (68) or about half their 48,334 square kilometers of submarine banks (69).

Coral reefs and the associated white sand beaches are major tourist attractions in the coastal tropics. In the last 50 years, for example, the coastal-based tourist industry of the Bahamas generated 55 percent of the country's gross national product (70). Between 1972 and 1981, the number of tourist resorts in the Maldives increased from 2 to 37, and the number of overseas visitor arrivals rose to 60,358 (71).

With the increase in tourism, the international coral curio trade has grown rapidly. In 1983, for example, the Philippines exported 244 tons of coral to the United States (72). Coral collecting and mining removes the animals responsible for formation of the reef. Such a loss reduces the resistance of the reef to wave action, increases the likelihood of storm damage and beach erosion, and reduces the aesthetic qualities of the reef. The long-term effects on reef structure are not yet known. However, there seems to be a positive correlation among fish, standing biomass, and the proportion of coral cover (73).

Sediment pollution from mismanaged upland areas and destruction by mining or blast fishing are the primary threats to reef ecosystems (74). Coral mining and blast fishing are particularly destructive because most coral species grow very slowly, effectively rendering them a non-renewable resource. Additional pressures include dredge and fill operations, overfishing, water pollution, large volumes of freshwater from river diversions or storm runoff, and destruction by collectors and tourists. Starfish, particularly the crown-of-thorns starfish (*Acanthaster planci*), significantly damage reefs by feeding on the live coral. Table 9.7 is a preliminary list of key pressures to reef ecosystems, and the regions of major concern.

There are few estimates of the ecological conditions of coral reefs over the past 20 years. Various reports for specific time periods indicate that the coral cover is declining. An exception is Kaneohe Bay, Oahu, Hawaii. Surveys done there five years before and five years after most of the sewage was diverted to an offshore site show that live coral coverage in the lagoon had almost doubled (75).

The majority of reefs in the Philippines are in fair to poor condition, with two thirds of the stations sampled in 1982 having less than 50 percent live coral cover (76). This decline is attributed to siltation accompanying massive deforestation, blast fishing, and coral harvest (77). Six of the more commonly collected commercial coral species in Philippine reefs have declined by 73 percent (78).

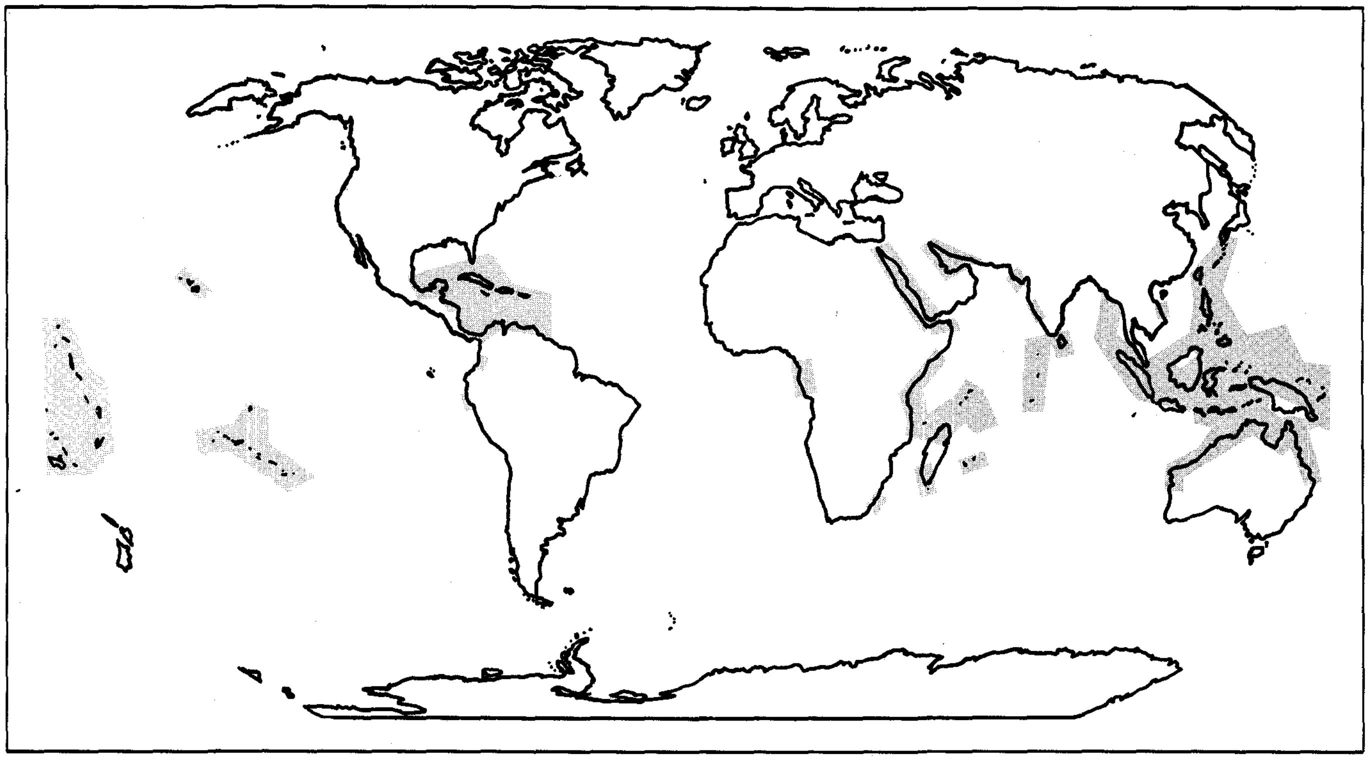
A 1984 survey of some reefs along the Tanzanian coast revealed that the luxuriant reef growth of the 1960s was reduced to rubble by extensive blast fishing. The loss of reef habitat caused the decline of a formerly lucrative

## Table 9.6 Major Causes of Recent Degradation to Seagrass Ecosystems by Region

| | Indo-Pacific | South Asia | Southeast Asia | East Africa | West/Central Africa | Middle East | Wider Caribbean |
|---|---|---|---|---|---|---|---|
| Direct Destruction: | | | | | | | |
| Dredge/Fill | + | + | + | | | + | + |
| Trawling | + | | | + | | + | |
| Siltation: | | | | | | | |
| Dredge/Fill | + | + | + | | | + | + |
| Land Runoff | | | | + | + | | |
| Pollutants: | | | | | | | |
| Chemical | + | | | | + | | + |
| Domestic | + | | | | | | |
| Oil | | | | | + | | + |
| Thermal | | | | | | | + |

**Sources:**
1. G.J. Bakus, University of Southern California, Los Angeles, 1985 (personal communication).
2. N.L. Berwick, "Guidelines for the Analysis of Biophysical Impacts to Tropical Coastal Marine Resources," in *Proceedings of the Bombay Natural History Society Centenary Seminar: Conservation in Developing Countries—Problems and Prospects*, December 1983 (Bombay, India, in press, 1985).
3. E.D. Gomez, University of the Philippines, Marine Sciences Center, Quezon City, 1985 (personal communication).
4. P.N. Lal, "Environmental Implications of Coastal Development in Fiji," *AMBIO*, Vol. 13, Nos. 5-6, pp. 316-321 (1984).
5. A. Thorhaug, "Biology and Management of Seagrass in the Caribbean," *AMBIO*, Vol. 10, No. 6, pp. 295-298 (1981).
6. Zieman, 1982, Reference 42.

**Figure 9.4 Distribution of the World's Coral Reefs**



**Source:** Snedaker and Getter, 1985, Reference 25.

fishery. An alarming increase in beach erosion also threatens tourist hotels in the area (79). Over the past 30 years, siltation from extensive dredging and overfishing have caused a 95 percent decline in the live coral coverage of coral reefs fringing the southern coast of Hainan Island (part of the People's Republic of China) in the South China Sea (80).

Starfish predation devastated coral reefs in the Ryukyu Archipelago of Japan in 1974 (81), causing an estimated 75 percent loss of live coral cover. Siltation from agricultural runoff, landfill, and road and hotel construction, coupled with little or no recovery from starfish predation, further decreased the live coral cover in the area to a mere 1–2 percent (82).

Although awareness of the importance and vulnerability of reef ecosystems has been growing, only about half the countries with reefs have at least one or more established and managed marine protected area. An estimated 70 percent of the countries without such reserves, however, have proposed or interim-designated marine protected areas (83).

### Trends in Mangroves, Seagrasses, and Coral Reefs

The limited long-term quantitative data on these three tropical coastal ecosystems preclude assessment of the resources and areas that are critically threatened. An indirect assessment of resource vulnerability, however, can be derived from an analysis of resource abundance and development activity where data are available. (See Figures 9.5, 9.6, and 9.7). The analysis assumes that vulnerability is determined primarily by the extent of the resource, the economic capacity for exploitation of the resource, the density of the human populations available to exploit the resource, and the growth rate of these populations (85). This indirect assessment indicates that all three resources appear to be at greatest risk in Central America, followed by Southeast Asia. Overall, coral reefs appear to be the most threatened, particularly in South and Southeast Asia, followed by seagrasses and mangroves. (Also see Part IV, Chapter 10 "Oceans and Coasts," Table 10.3.)

## RECENT DEVELOPMENTS

### OCEAN DISPOSAL OF RADIOACTIVE WASTES

During the 1980s, public concern about the treatment and disposal of radioactive wastes has grown markedly. With ocean disposal as an option, concern has been manifested primarily through the London Dumping Convention (LDC), the global treaty that regulates the dumping of wastes in the oceans beyond the limits of national jurisdiction.

At their seventh meeting in February 1983, parties to the LDC adopted a resolution to prohibit low-level radioactive waste dumping pending a scientific review of the risks. Until that time, European countries (the United Kingdom, Belgium, Switzerland, and the Netherlands) had been dumping these wastes at a depth of 4,000 meters in a small area of the Atlantic Ocean off the coast of Spain.

At the 1984 LDC meeting, more specific terms of reference were formulated for the scientific review. The matter was again considered at the LDC meeting in London in September 1985.

Tensions and disagreements were strong between the countries opposed to dumping and those that are generating radioactive wastes and are anxious to dispose of them as soon as possible. Just before the meeting, Great Britain threatened to resume dumping even if the moratorium were not lifted; some observers felt that the United States might follow suit. In any event, these threats proved ineffective and the LDC adopted a resolution—by a vote of 25 in favor, 6 opposed, and 7 abstentions—that provides for an indefinite moratorium on low-level waste disposal pending completion of important risk-related scientific and other studies.

The six countries voting against the resolution were Great Britain and Switzerland, which both had been carrying out ocean disposal prior to the moratorium, Canada, France, South Africa, and the United States. The United States has not dumped radioactive wastes at sea since 1970, but key officials within some federal agencies—particularly the Departments of Defense and Energy—continue to promote the sea disposal option.

Central to the continuing controversy over low-level waste disposal are the difficulties of establishing a common basis for assessing the social, economic, scientific, and technological factors and of the need for a thorough assessment of the land-based versus sea-dumping options. These issues will be considered in detail by the parties to the LDC. At their next formal meeting in the fall of 1986, government members and observers will develop detailed terms of reference for carrying out the studies mandated by the 1985 resolution.

Another important decision that will limit ocean disposal of radioactive wastes was made in 1985 when the South Pacific Forum (the 13 independent and self-governing states in the Southwest Pacific) adopted the South Pacific Nuclear Free Zone Treaty (SPNFZ). The SPNFZ reflects the long-standing concerns of Forum members about testing in the region, proposals to dump nuclear wastes there, and other nuclear issues. Under the treaty, Forum members agreed not to dump radioactive wastes within the zone, not to help anyone dump wastes at sea, and to support a regional convention's preclusion of ocean dumping of radioactive wastes by anyone in the region.

## FAO WORLD CONFERENCE ON FISHERIES MANAGEMENT AND DEVELOPMENT

Changes in international ocean law and the fact that catches are approaching the limits of conventional resources have directed attention toward marine fisheries. Internationally, attention culminated in the U.N. Food and Agriculture Organization's (FAO) 1984 World Conference on Fisheries Management and Development.

FAO hailed the conference as "a unique and historic occasion in the evolution of the world's fisheries." It was the first time that almost all nations in the world came together to reach agreement on a strategy for the world's fisheries. It was attended by 147 countries and 67 international fishing organizations.

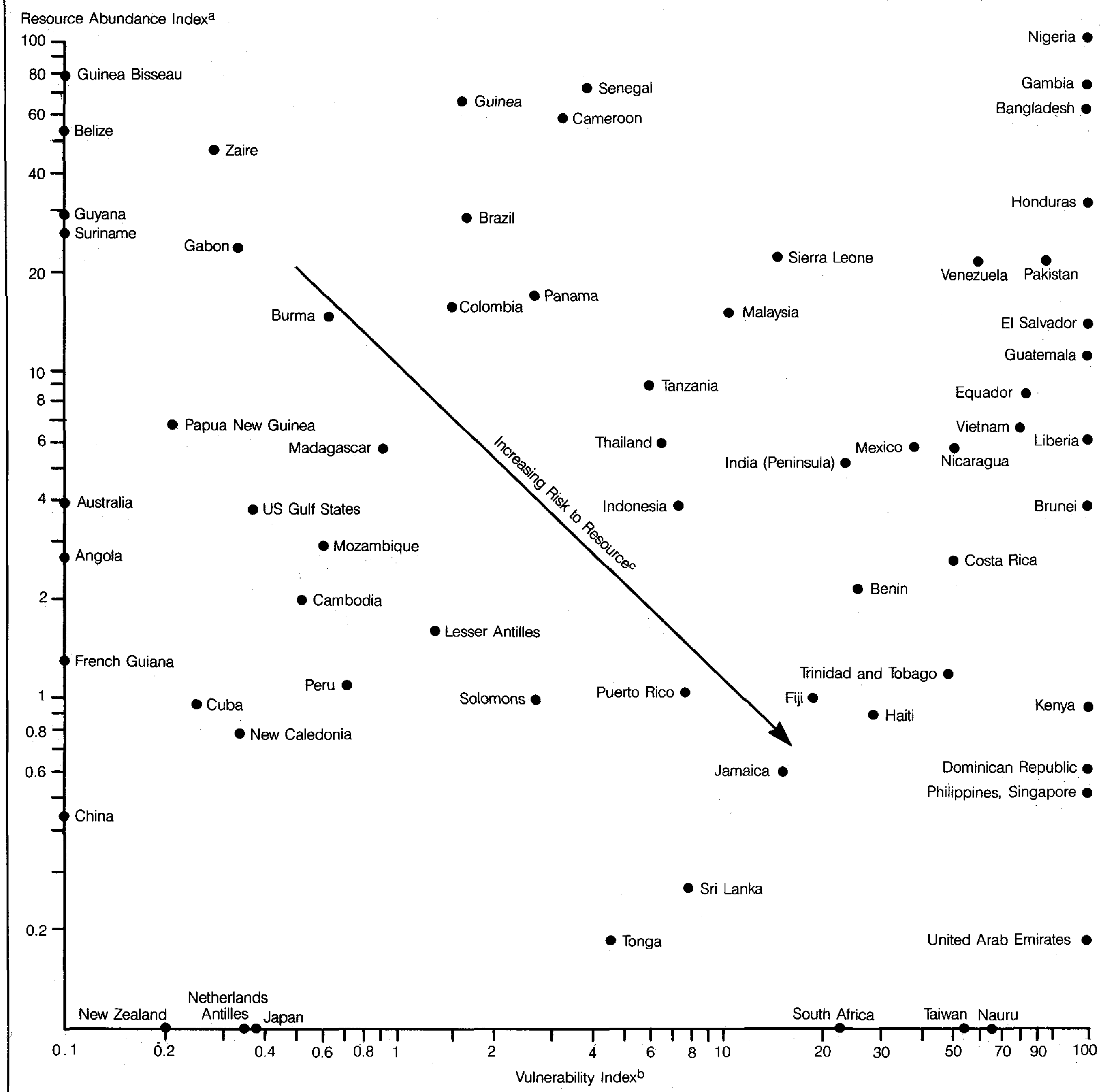
The two major products of the conference were a Strategy for Fisheries Management and Development, and a set of Action Programs to implement that strategy. It is, however, difficult to see how nations will be able to use the strategy as a practical guideline to manage or develop their fisheries—most of the 116 points are unexceptional, if not platitudinous. Without some guidance on which points are important, this list risks encouraging governments to select the points that match what they

**Table 9.7 Major Causes of Degradation of Coral Reefs, by Region**

| | Indo-Pacific | South Asia | Southeast Asia | East Asia | East Africa | Middle East | Wider Caribbean |
|---|---|---|---|---|---|---|---|
| Siltation: | | | | | | | |
| Dredge/Fill | + | | + | + | | + | + |
| Land Runoff | + | + | + | + | + | | + |
| *Destructive Fishing* | + | | + | + | + | | + |
| Intense Localized Fishing Effort | + | | + | | | + | + |
| Construction Materials: | | | | | | | |
| Reef Mining | + | + | + | + | + | | |
| Sand Dredging | + | + | + | + | | + | |
| Coastal/Offshore Mining | + | + | + | | | | |
| Curio Trade | + | + | + | + | + | + | + |
| Tourism | + | | + | | | | + |
| *Pollutants:* | | | | | | | |
| Chemical | + | + | + | | | | + |
| Domestic | + | + | + | | + | | + |
| Nuclear | + | | | | | | + |
| Oil | + | | + | | | + | + |
| Natural Stress: | | | | | | | |
| Storms | + | | + | | | | + |
| Predation by Starfish | + | | + | + | | | |

**Sources:**
1. G.J. Bakus, University of Southern California, Los Angeles, 1985 (personal communication).
2. N.L. Berwick, "Guidelines for the Analysis of Biophysical Impacts to Tropical Coastal Marine Resources," *Proceedings of the Bombay Natural History Society Centenary Seminar: Conservation in Developing Countries—Problems and Prospects*, December 1983 (Bombay, India, in press, 1985).
3. A.L. Dahl, "Oceania's Most Pressing Environmental Concerns," *AMBIO*, Vol. 13, Nos. 5-6, pp. 296-301 (1984).
4. Gomez, 1980, Reference 77.
5. P.N. Lal, "Environmental Implications of Coastal Development in Fiji," *AMBIO*, Vol. 13, Nos. 5-6, pp. 316-321 (1984).
6. Muzik, 1985, Reference 82.
7. R.V. Salm, "Coral Reefs of the Western Indian Ocean: A Threatened Heritage," *AMBIO*, Vol. 12, No. 6, pp. 349-353 (1983).
8. Soysa *et al.*, 1982, *Reference 65.*

**Figure 9.5 Comparative Abundance and Vulnerability of Mangroves, by Country**




**Notes:**

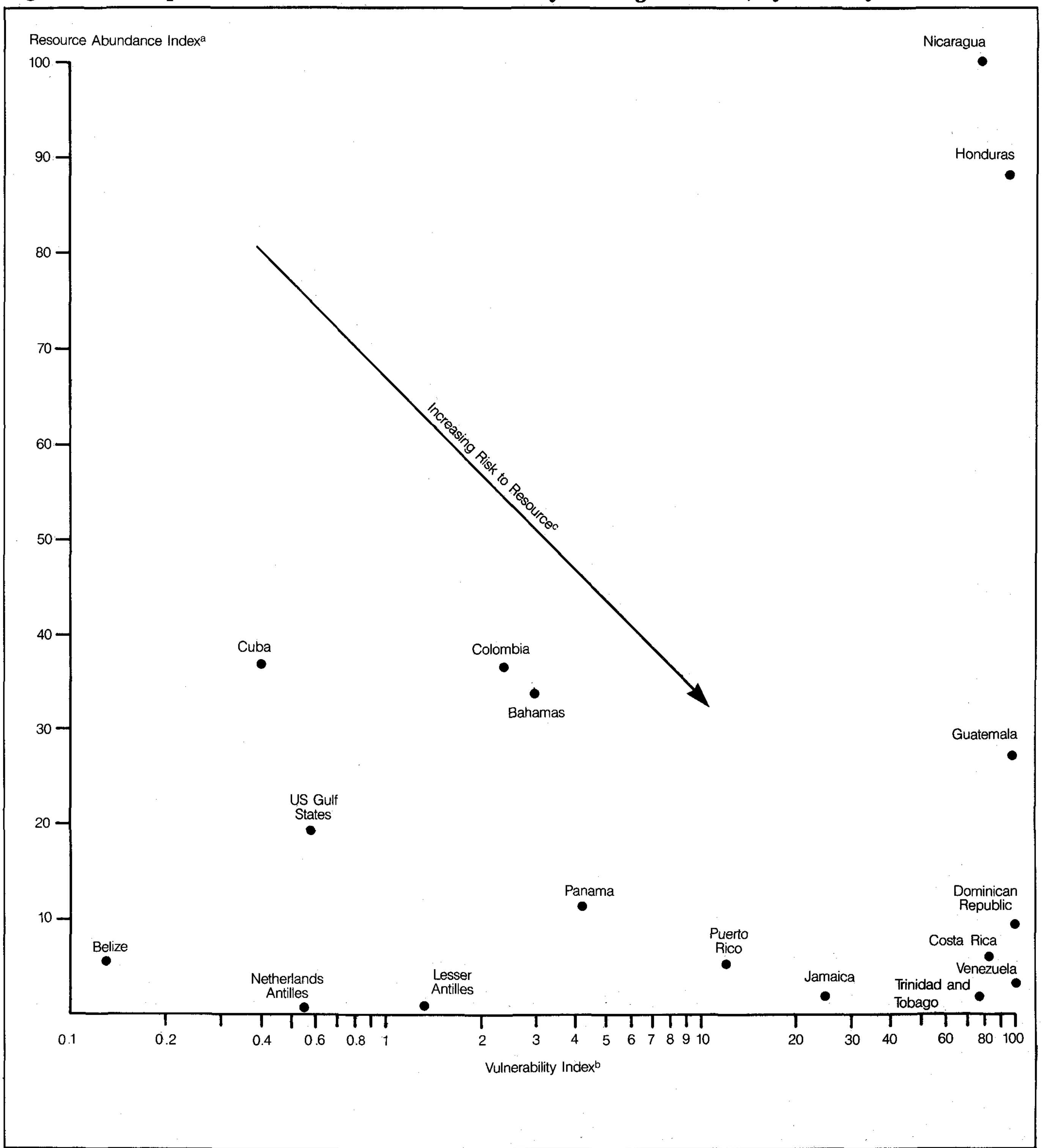
a. The resource abundance index was calculated by dividing the area of mangroves by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national product per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

**Source:** N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

**Figure 9.6 Comparative Abundance and Vulnerability of Seagrass Beds, by Country**




**Notes:**

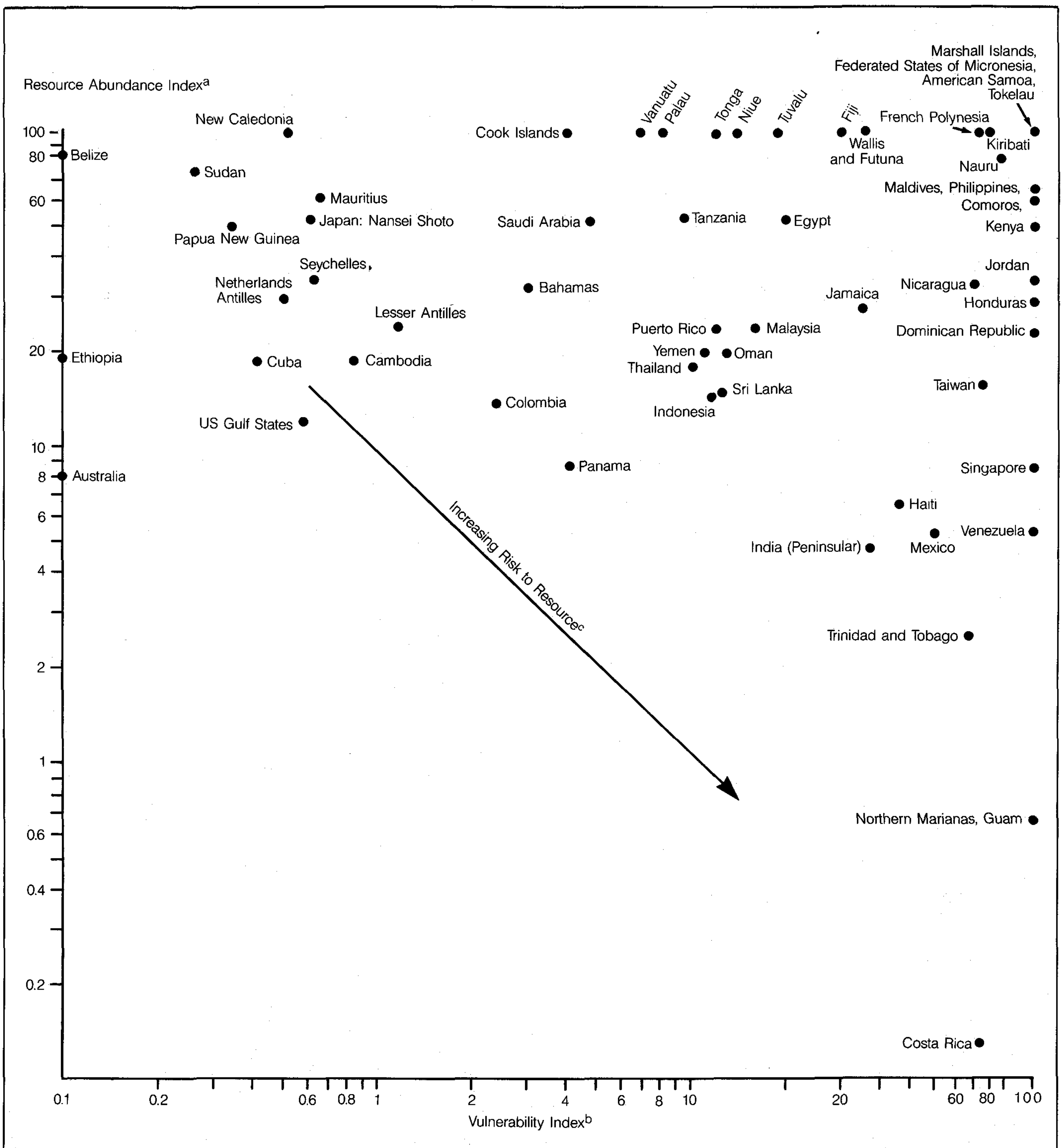
a. The resource abundance index was calculated by dividing the area of seagrass beds by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

**Source:** N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

**Figure 9.7 Comparative Abundance and Vulnerability of Coral Reefs, by Country**




**Notes:**

a. The resource abundance index was calculated by dividing the linear extent of coral reefs by the country coastline length and then normalizing the results to a 0-100 scale.

b. The vulnerability index was calculated by multiplying the gross national product per capita for each country by the population density raised to the power of the natural rate of increase; again, the results were normalized to 100.

c. The potential risk to the resource increases with decreasing areal extent and increasing probability of development.

**Source:** N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, Washington, D.C., unpublished monograph, submitted, 1985).

are already doing, and does not challenge governments to critically examine present policies and make the drastic changes that are often needed.

The action programs, which are intended to assist developing countries in implementing the strategy, were estimated to require an expenditure of $15 million over a five-year period, and the conference urged bilateral and international donor agencies to provide the necessary support. Even if the money is forthcoming, it will provide only a beginning. Changes that involve major restructuring of national fisheries may require much larger sums. At the minimum, better management will require better trained people in stock assessment, economic analysis, and probably most of all in the new profession of fisheries management. If world fisheries are to be managed on a sustainable basis, much more work is going to be required.

## THE ANTARCTIC

As the last major part of the earth's surface that is still relatively undisturbed, the Antarctic continent has received increasing attention from conservationists in recent years. Human activities on this continent have been governed by the 1959 Antarctic Treaty. In addition, to promote conservation in the Antarctic, parties to the Antarctic Treaty concluded the Convention for the Conservation of Antarctic Seals (1972) and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR, in 1980); both are in force.

Four issues are the subject of much recent discussion: the effectiveness of CCAMLR; the potential impacts of mineral exploitation; further development of protection measures; and increasing activity levels and concentrations, particularly where land or ice meets the sea.

CCAMLR, which held its fourth annual session at Hobart, Australia, in September 1985, has moved more slowly toward effective conservation measures than some had hoped, but perhaps no more slowly than other comparable international organizations. Although in many ways it is similar to several international fishery commissions, CCAMLR is the first commission to be charged specifically with consideration of the ecosystem as a whole, rather than of individual species, when making decisions. This is a considerable undertaking, but CCAMLR is moving toward the task effectively and has, among other actions, set up a subcommittee within the scientific committee to study ecosystem monitoring.

A particular disappointment is CCAMLR's slowness in applying effective measures to conserve fish stocks, some of which, especially Antarctic cod (*Notothenia rossii*), were depleted by heavy fishing from 1969 onward (86). The Soviet Union, for example, took half a million tons of Antarctic cod between 1969 and 1971. Subsequent catches have averaged only a few thousand tons annually. Current cod stocks are reported to be only a few percent of their former level (87). However, to a large extent these stocks were depleted prior to CCAMLR, and current management actions are little more than locking the stable door after the horse has fled.

Another concern is data. Many scientists, especially from non-fishing countries, have asked for detailed information on fishing operations in order to monitor changes in fished stocks. The fishing countries are unwilling to supply all these data because of the work involved. Further, it is not clear how useful such detailed information would be. How much data will actually be supplied is not known.

Fortunately, this matter has become less urgent with the decline in the krill fishery. After reaching a peak of over half a million metric tons in 1981–82, total catches have fallen to less than 130,000 metric tons in 1983–84 in the Soviet fishery, largely for technical reasons (88).

Conservation of the coastal zones received considerable attention at a symposium organized by the International Union for Conservation of Nature and Natural Resources (IUCN) and the Scientific Committee on Antarctic Research (SCAR) in Bonn in April 1985. The fringes of land along the Antarctic peninsula, a few other parts of the continent, and the Antarctic and sub-Antarctic islands are the only parts of Antarctica where any significant life exists on land. But the most easily accessible land and ice shelf areas are those that are most attractive both for human activities and for the large populations of penguins and marine mammals such as seals. These and the adjacent inshore areas are particularly vulnerable to human disturbance. Through its measures on conservation, the Antarctic Treaty already prohibits many activities that could disturb the ecosystem. However, there is a fear that even non-exploitative activities, such as the presence of many tourists or those engaged in scientific work, can be harmful, and consideration of further protective measures is being given within the Antarctic Treaty mechanism and by IUCN and SCAR. Such measures include the identification of additional protected areas, measures to deal with increased activity in Antarctica, and attention to data management.

In the long term, the greatest threat to the Antarctic environment is likely to come from mineral exploration and exploitation. No commercially attractive deposits have yet been identified. Moreover, the extreme physical conditions would make any such activity extremely costly, although the discovery of large concentrations of valuable minerals and shifts in technology or market factors could eventually make some forms of mineral extraction attractive. Recognizing that negotiations on this subject are bound to be long and difficult, the Antarctic Treaty powers are now engaged in discussions, begun in 1982, to negotiate a formal agreement similar to those on seals and marine living resources.

## COASTAL RESOURCE MANAGEMENT IN THE ASEAN COUNTRIES

Resource use and management of coastal margins has always been practiced, but comprehensive, integrated coastal zone management and development were formalized only in the early 1970s. Recent coastal management activities and policy reform have been particularly prevalent among the coastal nations of Southeast Asia. They include:

■ Adoption of a United Nations Environment Program Regional Seas Action Plan in April 1981 by the five member states of the Association of Southeast Asian Nations (ASEAN)—Indonesia, Malaysia, the Philippines, Singapore, and Thailand—paved the way for broader cooperation on common environmental concerns. The priority projects of the Action Plan during its initial phase in 1982–83 included: combatting oil pollution from offshore and onshore activities and from tanker traffic, reducing coral reef destruction from blast fishing, halting destruction of mangrove swamps by fish pond operators and loggers, and installing sewage treatment plants along coasts where shellfishing is predominant. The ultimate goal of the Action Plan is the incorporation of environmental considerations into all aspects of economic development in the region. If successful, the Action Plan is expected to act as a nucleus for the development of a wider program in the area that would encompass the states bordering on the Bay of Bengal, South China Sea, East China Sea, and northern Australia, in addition to the five nations already participating.

■ Implementation of the five-year ASEAN/U.S. Agency for International Development (U.S. AID) Coastal Resources Management Project in 1986 strengthened the capability of ASEAN countries to manage their renewable coastal resources on a sustainable basis by improving technical and institutional approaches to managing living coastal resource systems. In order to accomplish this goal, an intersectoral and interdisciplinary systems approach to collecting, analyzing, documenting, and disseminating information on trends in living coastal resources exploitation is being carried out. These efforts are coupled with developing institutional arrangements that link applied environmental and socioeconomic research to coastal resources assessment, planning, and management.

■ Additional joint ASEAN/bilateral donor assistance programs are being developed for various elements of ASEAN's cooperative program on marine sciences. The Canadian International Development Agency (CIDA) has signed a Memorandum of Understanding with ASEAN for studies on resource management and development and for pollution monitoring programs, although final arrangements for funding are not complete. Similarly, Canada's International Development Research Center (IDRC) is pursuing arrangements for providing further support to ASEAN in the marine sciences sector, particularly by strengthening the regional environmental study centers. Official responses from Japan and the European Economic Community (EEC) are reportedly in progress. As part of the ASEAN/Australia program, a project to generate quantitative baseline information on the community structure, distribution, and productivity of coastal ecosystems, with particular emphasis on mangroves, coral reefs, and interecosystem relationships, has been defined.

■ Multilateral donor assistance will continue to include the United Nations Environment Program (UNEP) support to the Coordinating Body on the Seas of East Asia, and the Asian Development Bank's fisheries and aquaculture development program.

■ The proposed U.S. AID-sponsored Aquatic Resource Development Project for Indonesia will focus on fisheries development and marketing, shrimp aquaculture, and a model integrated coastal resource research project. A major feature of the project is policy and institutional structural development to ensure sustainable fisheries management by considering impacts on other coastal resources.

## References and Notes


1. U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture* (FAO, Rome, 1984), p. 63.
2. S. Holt and M. Segnestam, "The Seas Must Live: Why Coastal and Marine Protected Areas Are Needed," Paper presented at the Third World Congress on National Parks at the Coastal and Marine Workshop (Bali, Indonesia, 1982).
3. U.N. Food and Agriculture Organization (FAO), *Utilization of Fish and Its Role in Human Nutrition* (FAO, Committee on Fisheries, Rome, 1981), p. 11.
4. The World Bank, *Fishery Sector Policy Paper* (The World Bank, Washington, D.C., 1982), p. 18.
5. U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics*, Vol. 55 (FAO, Rome, 1983), p. 18.
6. *Op. cit.* 3, p. 4.
7. *Op. cit.* 1, p. 63.
8. J.A. Gulland, "Developing Countries and the New Law of the Sea," *Oceanus*, Vol. 22, No. 1, pp. 36–42.
9. U.N. Food and Agriculture Organization (FAO), *Review of the State of World Fishery Resources,* Fish Circular 710, Revision 4 (FAO, Rome, 1985), pp. 4–6 and p. 40
10. International Commission for the Northwest Atlantic Fisheries (ICNAF), *Proceedings of the Annual Meetings, Redbooks*, 1970–76 (ICNAF, Dartmouth, Canada).
11. J.A. Gulland, "World Resources of Fisheries and Their Management," in *Marine Ecology: A Comprehensive, Integrated Treatise on Life in Oceans and Coastal and Coastal Waters*, Vol. 5, Part 2 (John Wiley and Sons, New York, O. Kinne, Ed., 1983), pp. 876–878.
12. *Ibid.*, pp. 883–890.
13. *Op. cit.* 9, p. 39.
14. *Op. cit.* 11, pp. 839–1062.
15. J.A. Gulland, "How Much of the World's Fisheries Lie Within EEZs?," *Marine Policy*, Vol. 8, No. 4 (1984), p. 359.
16. J.A. Gulland, *The Fish Resources of the Ocean* (Fishing News (Books) Ltd., West Byfleet, England, 1971), Table 54, p. 251.
17. Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), *Report of the Third Meeting of the Scientific Committee* (CCAMLR, Hobart, Australia, 1984), p. 238.
18. J. Troadec, *et al.*, "A Review of Some Pelagic Stocks in Other Areas," in *Rapports et Procès-verbaux of the International Council for the Exploration of the Sea*, No. 199 (Copenhagen, 1980), pp. 252–277.
19. J.E. Maragos, *et al.*, "Development Planning for Tropical Coastal Ecosystems," in *Natural Systems for Development* (MacMillan Publishing Co., R.A. Carpenter, Ed., New York, 1983), p. 236.
20. W.N. Lindall and C.H. Saloman, "Alteration and Destruction of Estuaries Affecting Fishery Resources of the Gulf of Mexico," *Marine Fisheries Review*, Vol. 39, p. 1262 (1977).
21. G. Hartshorn, *Belize Country Environmental Profile: A Field Study* (U.S. Agency for International Development, Washington, D.C., 1984), p. 54.
22. R.E. Johannes, "Traditional Law of the

Sea in Micronesia," *Micronesia*, Vol. 13, No. 2, pp. 121–127 (1977).
23. J.P. Levy, "Introduction and Summary," in *Inter-Regional Seminar on Development and Management of Resources in Coastal Areas* (German Foundation for International Development/United Nations, K.S. Szekielda and B. Breur, Eds., 1976).
24. J.T. McGill, *Coastal Classification Maps* (2nd Coastal Geography Conference, Louisiana State University, Coastal Studies Institute, Baton Rouge, 1959).
25. S.C. Snedaker, and C.D. Getter, *Coasts: Coastal Resources Management Guidelines*, Renewable Resources Information Series: Coastal Publication No. 2 (Research Planning Institute, Inc., Columbia, South Carolina, 1985), p. 23.
26. L.S. Hamilton and S.C. Snedaker, Eds., *Handbook for Mangrove Area Management* (Environment and Policy Institute, East-West Center; International Union for Conservation of Nature and Natural Resources; United Nations Educational, Scientific and Cultural Organization; United Nations Environment Program, 1984).
27. P. Martosubroto and N. Naamin, "Relationship between Tidal Forests (Mangroves) and Commercial Shrimp Production in Indonesia," *Market Reseach in Indonesia*, Vol. 18, p. 85 (1977).
28. P.N. Lal, "Mangroves and Secondary Productivity: Fishes Associated with Mangroves in Wairiki Creek, Fiji," in *Mangrove Resource Management*, Technical Report No. 5, Proceedings of an Interdepartmental Workshop (Ministry of Agriculture and Fisheries, Fisheries Division, Suva, 1983), pp. 19–20.
29. *Op. cit.* 26, p. 25.
30. *Op. cit.* 26.
31. H.T. Odum, *et al.*, *The Ecology of Mangroves of South Florida: A Community Profile* (U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services, Washington, D.C.), p. 74.
32. *Op. cit.* 25, p. 31.
33. K.H. Mann, *Ecology of Coastal Waters: A Systems Approach, Studies in Ecology*, Vol. 8 (University of California Press, Berkeley, 1982), p. 51.
34. P. Saenger, *et al.*, "Global Status of Mangrove Ecosystems," *The Environmentalist*, Vol. 3, Supplement No. 3 (1983).
35. Republic of the Philippines, *The Philippine Environment* (Republic of the Philippines, Ministry of Human Settlements, National Environment Protection Council, 1979).
36. *Op. cit.* 26, p. 25.
37. A. Terchunian, *et al.*, *Mangrove Mapping in Ecuador: The Impact of Shrimp Pond Construction* (unpublished manuscript, 1985), p. 9.
38. R.R. Twilley, *An Analysis of Mangrove Forests along the Gambia River Estuary: Implications for the Management of Estuarine Resources*, River Resources Team Report (University of Michigan Gambia River Basin Studies, 1984), p. 40.
39. *Ibid.*, p. 37.
40. *Op. cit.* 26, p. 9.
41. R. Coles and W. E. Long, *Areas of Prawn Nursery Grounds on the East Queensland Coast between Cairns and Cape York* (Queensland Department of Primary Industries, Northern Fisheries Research Center, preliminary draft, Cairns, Queensland, 1985), p. 1.
42. J.C. Zieman, *The Ecology of Seagrasses of South Florida: A Community Profile* (U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services, Washington, D.C., 1982), Chapters 6–7.
43. P.W. Basson, *et al.*, *Biotypes of the Western Arabian Gulf: Marine Life and Environments of Saudi Arabia,* 2nd Ed, (ARAMCO Department of Loss Prevention and Environmental Affairs, Dhahran, Saudi Arabia, 1981), pp. 105–106.
44. N.L. Berwick and R. Chamberlin, "Systems Analysis for Integrating Tropical Coastal Resources with Wastershed Use," in *Proceedings of the Fifth International Coral Reef Congress* (Papeete, Tahiti, in press, 1985).
45. J.C. Zieman, "Tropical Sea Grass Ecosystems and Pollution," in *Tropical Marine Pollution* (Elsevier Scientific Publishing Company, Elsevier Oceanography Series 12, E.J.F. Wood and R. E. Johannes, Eds., Amsterdam, Holland, 1975) pp. 63–74.
46. M.L. Cambridge and A.J. McComb, "The Loss of Seagrasses in Cockburn Sound, Western Austrialia, I: The Time Course and Magnitude of Seagrass Decline in Relation to Industrial Development," *Aquatic Botany*, Vol. 20, p. 229 (1984).
47. M.L. Cambridge, *et al.*, "The Loss of Seagrasses in Cockburn Sound, Western Australia, II: Possible Causes of Seagrass Decline," *Aquatic Botany* (in press, 1985).
48. G.R. Bastyan, Center for Water Research, University of Western Australia, Nedlands, West Australia, 1985 (personal communication).
49. B.J. Yokel, "Estuarine Biology," in *Rookery Bay Land Use Studies: Environmental Planning Strategies for the Development of a Mangrove Shoreline* (Conservation Foundation, Washington, D.C., 1975).
50. J.L. Taylor and C.H. Saloman, "Some Effects of Hydraulic Dredging and Coastal Development in Boca Ciega Bay, Florida," *U.S. Fish and Wildlife Service Fisheries Bulletin*, Vol. 67, No. 2, pp. 213–241 (1968).
51. J.C. Zieman, 1985 (personal communication).
52. S.V. Smith, "Coral Reef Area and Contributions of Reefs to Processes and Resources of the World's Oceans," *Nature*, Vol. 273, No. 5659, p. 225 (1978).
53. G.J. Bakus, "Wildlife Refuges and Endangered Species of the Hawaiian Islands and the Trust Territory of the Pacific Islands," in *Literature Review and Synthesis of Information on Pacific Island Ecosystems* (Documentation Associates, prepared for the U.S. Fish and Wildlife Service, Portland, Oregon, 1978), pp. 20–21.
54. C. Pétron, *et al.*, *Living Corals* (Les Editions du Pacifique, Papeete, Tahiti, 1980), p. 77.
55. P.R. Ehrlich, *et al.*, *Ecoscience: Population, Resources, Environment* (W.H. Freeman and Company, San Francisco, California, 1977), p. 163.
56. A.C. Alcala and T. Luchavez, "Fish Yield of the Coral Reef Surrounding Apo Island, Negros Oriental, Central Visayas, Philippines," in *Proceedings of the Fourth International Coral Reef Symposium,* Vol. 1 (Manila, Philippines, 1981), p. 69.
57. J.L. Munro, "Yields from Coral Reef Fisheries," *Fishbyte*, Vol. 2, No. 3, pp. 13–15 (1984).
58. J.L. Munro and D.M. Williams, "Assessment and Management of Coral Reef Fisheries: Biological, Environmental and Socio-Economic Aspects," Seminar C, in *Proceedings of the Fifth International Coral Reef Congress* (in press, 1985), p. 2.
59. A. Seogiarto, "Impact of Pollution on the Fishing Industry in Indonesia," in *Agriculture Ecological Society, SEA* (Second Biennial Meeting, Iloilo, Philippines, November 3-6, 1977), p. 17.
60. International Center for Living Aquatic Resources Management, "Fisheries Development and Management in Southeast Asia: Spotlight on the Philippines," *ICLARM Newsletter*, Vol. 1, No. 1, pp. 8–10 (1978).
61. N. Meith and R. Helmer, "Marine Environment and Coastal Resources in Southeast Asia: A Threatened Heritage," in *Ocean Yearbook* (University of Chicago Press, Illinois, E.M. Borgese and N. Ginsberg, Eds., 1983), p. 273.
62. R. Grandperrin, "Importance of Reefs to Ocean Production," *South Pacific Commission on Fisheries Newsletter*, Vol. 16, pp. 11–13 (1978).
63. S.K. Meltzoff, *Hunting for Tuna and Cash in the Solomons: A Rebirth of Artisanal Fishing in Malaita* (unpublished manuscript, 1985), p. 8.
64. S.R. Amerasinghe, "Coast Conservation," *Loris*, Vol. 14, No. 6, pp. 55–357 (1978).
65. C.H. Soysa, *et al.*, Eds. *Man, Land and Sea: Coastal Resource Use and Management in Asia and the Pacific* (Agricultural Development Council, Bangkok, 1982), p. 263.
66. R.B. Linsky, "Application of Information and Data to Coastal Development and Management," in *Proceedings of the Workshop on Coastal Area Development and Management in Asia and the Pacific* (East-West Center, Manila, and University Press of Hawaii, M.J. Valencia, Ed., Manila, 1981), p. 132.
67. R.V. Salm, "Coral Reefs of the Western Indian Ocean: A Threatened Heritage," *AMBIO*, Vol 12, No. 6, p. 351 (1983).
68. *Ibid.*
69. International Union for Conservation of Nature and Natural Resources (IUCN)/U.N. Environment Program (UNEP), *Conservation of Coastal and Marine Ecosystems and Living Resources of the East African Region*, UNEP Regional Seas Reports and Studies No. 11 (IUCN/UNEP, Nairobi, 1982), p. 28.
70. J.V. Beekuis, "Tourism in the Caribbean: Impacts on the Economic, Social and Natural Environments," *AMBIO*, Vol. 10, No. 6, p. 328 (1981).
71. R.V. Salm, "Man's Use of Coral Reefs," in *Coral Reef Management Handbook*

(United Nations Educational, Scientific and Cultural Organization, Regional Office for Science and Technology for South-East Asia, R.A. Kenchington and B.E.T. Hudson, Eds., Jakarta, Indonesia, 1984), p. 19.

72. S.M. Wells, "Stone Corals: A Case of CITES," *TRAFFIC Bulletin*, Vol. VII, No. 1, p. 10 (1985).

73. K.E. Carpenter, *et al.*, "The Influence of Substrate Structure on the Local Abundance and Diversity of Philippine Reef Fishes," in *Proceedings of the the Fourth International Coral Reef Symposium* (Manila), pp. 497–502.

74. E.D. Gomez, University of the Philippines, Diliman, Quezon City, 1985 (personal communication).

75. J.C. Maragos and P. Holthus, "Reef Corals In Kaneohe Bay: Six Years Before and After Termination of Sewage Discharges," in *Proceedings of the Fifth International Coral Reef Congress* (Oahu, Hawaii, in press, 1985).

76. Marine Sciences Center, "Investigation of the Coral Reef Resources of the Philippines, Phase III (Terminal Phase), Final Report (1982)," in National Environment Board, *Living Resources in Coastal Areas with Emphasis on Mangrove and Coral Reef Ecosystems* (ASEAN-Australia Cooperative Programs in Marine Science, Bangkok, Thailand, 1984).

77. E.D. Gomez, *Status Report on Research and Degradation Problems of the Coral Reefs of the East Asian Seas* (South China Sea Fisheries Development and Coordinating Program, Manila, Philippines, 1980), pp. 26–29.

78. *Op. cit.* 72, p. 10.

79. W.M. Kudoja, "The Tanzanian Coral Reefs at Risk," in *Proceedings of the Fifth International Coral Reef Congress* (Papeete, Tahiti, in press, 1985), p. 209.

80. B.L. Wu, "Coral Reefs of Hainan Island in the South China Sea," in *Proceedings of the Fifth International Coral Reef Congress* (Papeete, Tahiti, in press, 1985).

81. M. Nishihira and K. Yamazato, "Human Interference with the Coral Reef Community and *Acanthaster* Infestation at Okinawa," in *Proceedings of the Second International Coral Reef Symposium*, Vol. 1, pp. 577–590.

82. K. Muzik, "Dying Reefs of the Ryukyu Archipelago," in *Proceedings of the Fifth International Coral Reef Congress* (Papeete, Tahiti, in press, 1985).

83. International Union for Conservation of Nature and Natural Resources (IUCN), *IUCN Directory of Coral Reefs of International Importance* (IUCN Conservation Monitoring Center, draft, Cambridge, England, 1985).

84. N.L. Berwick, *Global Assessment of Tropical Nearshore Living Resources: Patterns, Processes, Policy and Impacts* (World Resources Institute/International Institute for Environment and Development, unpublished monograph, September 1985).

85. With limited quantitative data on the ecological conditions of the three tropical coastal ecosystems under scrutiny, an attempt was made to define resource abundance and vulnerability of each resource to anthropogenic change. The analysis involved devising a normalized resource abundance index and plotting it against a normalized "vulnerability" index for each of the 96 countries where data were available. The resource abundance index was calculated by dividing the areal extent of mangroves and seagrasses, and the linear extent of coral reefs, by the country coastline length and then normalizing the results to a 0–100 scale. The "vulnerability" index was calculated by multiplying the GNP per capita for each country by the population density raised to the power of the natural rate of increase; again the results were normalized to 100.
*Assumptions*
It was assumed that:
1. Resource vulnerability is positively correlated with a low abundance and a high probability of human-induced modification.
2. The potential for human modification is a function of population density, the rate of increase of the population, and the economic capacity for development as measured by GNP per capita; this index also constitutes an attempt to project future conditions in the face of a spotty literature on trends.
3. The variables that contribute to growing resource consumption and environmental degradation are multiplicative rather than additive (Ehrlich *et al.*, 1977, Reference 55), and the growth rate is an exponential function.
4. There existed a 1.5:1 ratio of reef resource to coastline length for "small" islands of less than 3,000 kilometers and therefore exclusive of "continental" islands such as Borneo and New Guinea, where no data were available.
The fourth assumption was based upon measurements of the linear dimension of reef as a function of coastline length for 27 volcanic and coral islands in Eastern Polynesia, and 107 of the more than 300 islands comprising Fiji. The 1.5:1 reef resource to coastline length was used for the thousands of poorly mapped and little-known Indo-Pacific islands that, for purposes of initial calculations, were assumed to have a coastline length of 1 kilometer unless the literature indicated otherwise. This is particularly significant when applied to the over 3,000 islands of the Marshalls and Carolines. This assumption awaits confirmation through more detailed inspection of charts and remote sensing data. Detailed measurements conducted during a resource inventory of Ponape indicate a 1.1:1 ratio and the range of variability for this assumption.

86. U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture, 1984* (FAO, Rome, 1984), p. 33.

87. E. Kemf, "Antarctic Fisheries Collapse?," *AMBIO*, Vol. 14, No. 1, pp. 54–55 (1985).

88. *Op. cit.* 17.

# 10. Atmosphere and Climate

Because air is a natural resource of environmental, economic, and social importance, it needs to be protected and managed (1). The driving force for monitoring, understanding, and controlling air quality is concern for both the environment and human health. No longer is air pollution seen as merely a local problem; it has regional, national, and international ramifications. Noxious emissions are often transported long distances and across national boundaries.

## CONDITIONS AND TRENDS

### EMISSIONS AND AMBIENT AIR QUALITY

On a global scale, various natural sources are responsible for a large proportion of the gases and particles emitted in the atmosphere. Nonetheless, in industrialized, urban, and densely populated areas, human activities are responsible for the vast majority of the air pollutants.

Programs exist in most industrialized countries to routinely monitor and assess air quality conditions, to observe trends, and to begin assessing the relationship between pollution and human health. Data from some of these national networks have become the information base for the global air quality network operated by the United Nations Environment Program (UNEP) in cooperation with the World Health Organization (WHO). Data from member states also provided information for the Organization for Economic Co-operation and Development (OECD) *State of the Environment Report 1985.* The major global, regional, and national monitoring networks are summarized in Table 10.1.

As of 1980, the UNEP Global Environmental Monitoring System (GEMS) network consisted of about 136 sites in 33 countries, but since then it has expanded considerably: today there are about 175 sites in 70 cities located in 42 countries (2). Table 10.1 lists the site classification and distribution. Although most of the monitoring sites are located in the OECD countries of Europe, North America, and the Pacific, many of the new sites are located in Third World cities. However, data from these sites will not be available for several years.

Globally, the traditional air pollutants of concern include: sulfur dioxide, nitrogen oxides, carbon monoxide, particulates, oxidants (ozone), volatile organic compounds, and lead. $SO_2$ and suspended particulate matter (SPM) are most commonly associated with fossil fuel combustion and, therefore, are used as indicators of pollution in urban environments. They are also the focus of UNEP's global monitoring network.

#### Ambient Standards and Guidelines for Pollutants

For the protection of human health and the environment, ambient guidelines have been established for major pollutants. However, exposure of individuals, and hence their health risks, are difficult to estimate because individuals

## Table 10.1 Major Monitoring Networks

| Sponsor | Scale | Classification of Site | Type of Monitoring/Data | Pollutant | Period of Trend Analysis |
|---|---|---|---|---|---|
| GEMS[a] | Global | Urban[b] Suburban[c] | Air Quality | $SO_2$ SPM | 1975-83 |
| Organization for Economic Co-operation and Development (OECD)[d] | Regional | | Air Quality Emissions | $SO_2$ SPM $NO_x$ CO | 1970-79 1979-84 |
| United States | National | Urban Suburban Rural | Air Quality Emissions | $SO_2$ $O_3$ $NO_x$ Pb CO | X |
| Japan | National | Urban Rural | X | $SO_2$ $O_3$ $NO_x$ CO HC | X |

$SO_2$ = sulfur dioxide, SPM = suspended particulate matter, $NO_x$ = nitrogen oxides, CO = carbon monoxide, $O_3$ = ozone, Pb = lead, HC = hydrocarbons
X = not available
**Notes:**
a. Global Environmental Monitoring System.
b. 60 percent of sites are city center, of which 50 percent are commercial, 25 percent industrial, and 25 percent residential.
c. 40 percent of sites are suburban, of which 50 percent are industrial, 50 percent residential, and very few commercial.
d. Not technically a network. Member countries submit data to OECD for compilation, but there is no formal network as in the other examples.
**Source:** Compiled by World Resources Institute.

move through various "zones" of different air quality, both indoors and outdoors (3). Table 10.2 lists the guidelines for $SO_2$ and SPM exposure limits developed by the World Health Organization to protect human health.

In addition to WHO guidelines, several countries have established their own national standards. The United States, for example, has National Ambient Air Quality Standards (NAAQS) for the major "criteria" pollutants. NAAQS are categorized as primary, or health-related standards, and secondary, or welfare-related (i.e., vegetation, materials, and visibility) standards. (See Table 10.3.) NAAQS are approximately comparable to the upper values of WHO guidelines (4).

Some of the air pollutants of concern to society are described individually in the following sections (5,6,7,8,9).

### *Sulfur Dioxide ($SO_2$)*

*Sources.* In North America, Europe, and many other industrialized areas, more than 90 percent of all sulfur in the ambient air comes from man-made emissions. The energy sector is the principal source of $SO_2$ emissions, principally from the combustion of coal and oil at power plants and secondarily from industrial processes. Among the OECD countries, only in Canada and Norway is the bulk of $SO_2$ emissions from the industrial sector, namely from smelters.

## Table 10.2 World Health Organization (WHO) Guidelines for Exposure Limits for $SO_2$ and Suspended Particulate Matter (SPM)

| | | SPM(μg/m³) | |
|---|---|---|---|
| | $SO_2^a$ (μg/m³) | Smoke Shade Method | Gravimetric High Volume Method |
| Yearly arithmetic average[b] | 40-60 | 40-60 | 60-90 |
| 98th percentile of the daily averages[c] | 100-150 | 100-150 | 150-230 |

**Notes:**
a. The range (i.e., 40-60 μg/m³) reflects scientific uncertainties about where adverse health effects are likely to begin.
b. Yearly arithmetic average applies to long-term exposures.
c. 98th percentile of the daily averages refers to short-term exposures and risks.
**Source:** United Nations Environment Program (UNEP)/World Health Organization (WHO), *Sulfur Oxides and Suspended Particulate Matter*, Offset Publication 57 (WHO, Geneva, 1979).

*Emission trends.* The pattern of fuel use generally coincides with emission trends. In a general sense, $SO_2$ emissions decreased in almost all OECD countries from 1970–79, remaining stable in just a few countries. Figure 10.1 illustrates the pattern of U.S. emissions of $SO_2$ and $NO_x$ from 1900–80. After a gradual increase from 1940–70, U.S. sulfur emissions decreased 36 percent from 1970–83. The downward trend in emissions continued for

## Table 10.3 U.S. National Ambient Air Quality Standards

| Pollutant | Primary (Health-Related) Averaging Time | Primary Concentration | Secondary (Welfare-Related) Averaging Time | Secondary Concentration |
|---|---|---|---|---|
| SPM | Annual geometric mean | 75 μg/m³ | Annual geometric mean | 60 μg/m³[a] |
| | 24-hour | 260 μg/m³ | 24-hour | 150 μg/m³ |
| $SO_2$ | Annual arithmetic mean | (0.03 ppm) 80 μg/m³ | 3-hour | 1300 μg/m³ (0.50 ppm) |
| | 24-hour | (0.14 ppm) 365 μg/m³ | | |
| CO | 8-hour | (9 ppm) 10 mg/m³ | Same as primary | |
| | 1-hour | (35 ppm) 40 mg/m³ | Same as primary | |
| $NO_2$ | Annual arithmetic mean | (0.053 ppm) 100 μg/m³ | Same as primary | |
| $O_3$ | Maximum daily 1-hour average | (0.12 ppm) 235 μg/m³ | Same as primary | |
| Pb | Maximum quarterly average | 1.5 μg/m³ | Same as primary | |

SPM = suspended particulate matter, $SO_2$ = sulfur dioxide, CO = carbon monoxide, $NO_2$ = nitrous oxide, $O_3$ = ozone, Pb = lead
**Note:** a. This annual geometric mean is a guide to be used in assessing implementation plans to achieve the 24-hour standard of 150 μg/m³.
**Source:** U.S. Environmental Protection Agency (EPA), 1985, Reference 5.

most OECD countries through 1984, including the United States, where emissions decreased by 19 percent. In the Federal Republic of Germany, trends in $SO_2$ emissions follow a pattern similar to the one observed in the United States: emissions increased from 1950 until around 1970, with a noticeable decline beginning in the mid-1970s (10,11). (See Figure 10.2.) Figure 10.3 illustrates the share of emissions of four of the major air pollutants in the three OECD regions in 1980.

While fuel combustion and industrial production have been increasing on the whole, downward trends in emissions can be attributed to decreased reliance on fossil fuels, with increased use of nuclear power, wider use of low sulfur fuels, energy conservation, and installation of some pollution control equipment (e.g., flue gas desulfurization).

*Air quality trends.* In the GEMS air quality monitoring network, the predominant trend for long- and short-term ambient $SO_2$ concentrations for 1973–80 is downward (12,13). (See Table 10.4.) More specifically, $SO_2$ concentrations decreased through the 1970s in large and industrialized cities of North America, the OECD Pacific region, and many European countries, except for Italy, where concentrations increased (14). (See Table 10.5.)

### *Suspended Particulate Matter (SPM) (15)*

*Sources.* Although natural sources of particulate matter are important, especially in arid regions with terrigenous soil and dust, artificial sources are of greater concern because particles have the potential for carrying toxic (including carcinogenic) trace substances, and the particulates themselves may be toxic. Fine particulates (aerosols) can be formed in the atmosphere as secondary pollutants from gaseous emissions.

The principal anthropogenic contributors to particulate matter include industrial processes and fuel combustion from stationary and mobile sources (especially diesel engines).

*Emission trends.* Despite economic growth, levels of SPM emissions have declined significantly from 1970–79 in major OECD countries like the United States, Japan, France, Germany, and the United Kingdom. Since 1979, economic growth has begun to slow down, and there have been further decreases in SPM. More specifically, total SPM emissions in the United States decreased by 69 percent from 1940–70 and since then have decreased another 62 percent. Table 10.6 summarizes U.S. emission estimates for the primary pollutants from 1940–83.

Such dramatic reductions are the result of changing energy policies that stress the use of coal washing equipment, conservation of energy, and the installation of dust control equipment. However, these impressive emission reductions have been offset by a corresponding increase in motor vehicle traffic since the 1960s. Further, the use of diesel cars has increased in several OECD countries, and diesel engines generate significantly higher emissions of fine and toxic particulates.

*Air quality trends.* The data indicate that the predominant trend for SPM concentrations at GEMS sites showed some improvement (16): 45 percent of the sites have decreasing annual averages; 10 percent of the sites show an upward trend for annual averages; and 50 percent of the industrial sites show a downward trend. (See Table 10.4.)

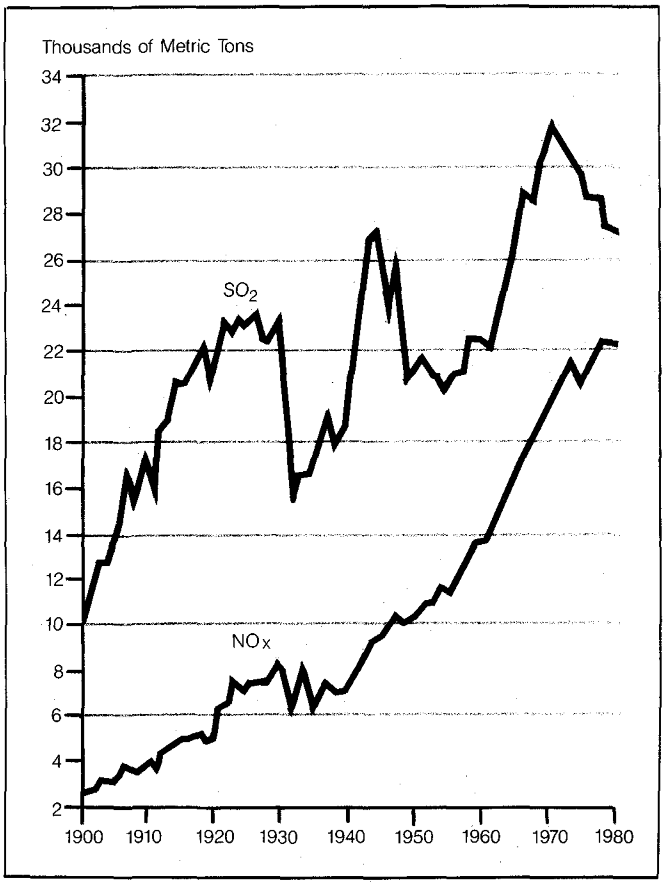
Likewise, in most OECD cities, the ambient particulate concentration from 1975–79 either fell or remained relatively stable. (See Table 10.7.) SPM levels decreased 20 percent in the United States from 1975–83 (17); in the Federal Republic of Germany, SPM concentrations decreased by 55 percent over the past two decades (18).

### *Overall Trends in $SO_2$ and SPM Pollution*

At the 52 sites in the GEMS network where $SO_2$ and SPM concentrations were measured simultaneously for at least 5 years, 30 percent showed decreasing annual average concentrations of both pollutants; 20 percent of the sites had stationary trends for both pollutants; and none of the sites showed upward trends for both pollutants (the remaining sites showed mixed trends).

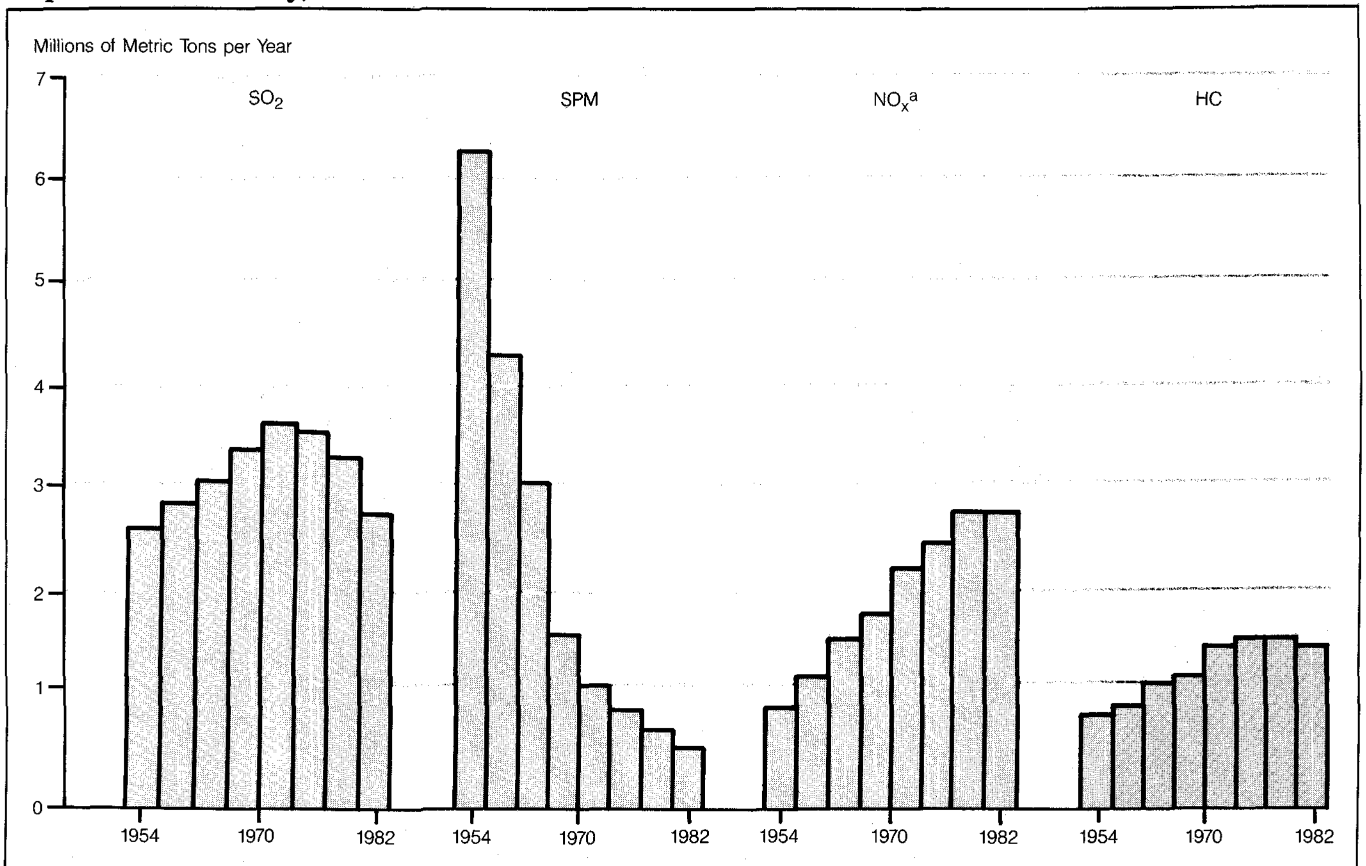
Sulfur dioxide and SPM pollution levels were also compared for cities in the GEMS network using only data representing substantially complete measurements at several sites within a city for 1976–80. The composite average was then calculated and plotted along with the

**Figure 10.1 Annual Emissions of $SO_2$ and $NO_x$ in the Coterminous United States, 1900–80**




**Source:** U.S. Environmental Protection Agency, 1985, Reference 5.

**Figure 10.2 Estimated Emissions of $SO_2$, SPM, $NO_x$, and Hydrocarbons in the Federal Republic of Germany, 1954–82**




**Note:** a. Calculated as $NO_2$.
**Source:** Federal Republic of Germany, Federal Ministry for Research and Technology, 1984, Reference 10.

range of annual averages at individual sites. (See Figures 10.4 and 10.5.) Composite $SO_2$ averages range from 17 micrograms per cubic meter for Auckland, New Zealand, to 207 micrograms per cubic meter in Milan, Italy. However, with SPM concentrations, the ranges among individual sites in each city are tighter. The composite averages extend in a fairly regular fashion from 59 micrograms per cubic meter in Tokyo to 142 micrograms per cubic meter in Zagreb, Yugoslavia. The unusually high average SPM concentrations for Tehran, Iran, and Calcutta, India, are not due entirely to industrial pollution; naturally high dust levels also contribute (19).

By and large, 1980 data from the GEMS network indicate that cities in Eastern Europe and the Third World are consistently more polluted with $SO_2$ and SPM than most (but not all) of the cities in OECD countries. Monitored cities in developing countries exhibited relatively higher values for suspended particulate matter than any of the OECD countries, with particularly high maximum values (ranging from 525 micrograms per cubic meter up to 2,221 micrograms per cubic meter) in Baghdad, Iraq; Teheran, Iran; Bombay, Calcutta, and New Delhi, India; Jakarta, Indonesia; Lahore, Pakistan; and Kuala Lumpur, Malaysia. These high levels are attributed to a combination of sources, mostly urban wood and charcoal fires for cooking, heating water, and fueling cottage industries (20).

Smoke concentrations (another way of measuring SPM) were also high in the South American cities of São Paulo, Brazil; Santiago, Chile; and Bogotá, Colombia (21). Since data for these countries are relatively recent (1975–80), it is not possible to detect long-term trends in air quality. However, available data indicate that smoke and particulate pollution are becoming serious problems in many Third World cities.

A similar picture emerges in Eastern Europe. High levels of smoke pollution in the range of 570–830 micrograms per cubic meter maximum values have been noted in East Berlin, German Democratic Republic; Prague, Czechoslovakia; Zagreb, Yugoslavia; and two cities in Poland, Warsaw and Wroclaw (22).

Once again the available data are too patchy to detect trends, but it seems apparent that Eastern Europe, in general, suffers from relatively higher levels of both $SO_2$ and SPM pollution than cities in OECD countries (23).

### *Nitrogen Oxides ($NO_x$)*

*Sources.* The major anthropogenic sources of $NO_x$ are the transportation sector and stationary fuel combustion from the industry and energy sectors. In urban areas, $NO_x$

gives the atmosphere a yellow-brown cast. Nitrogen oxides also play a central role in photochemical smog and oxidant (ozone) formation.

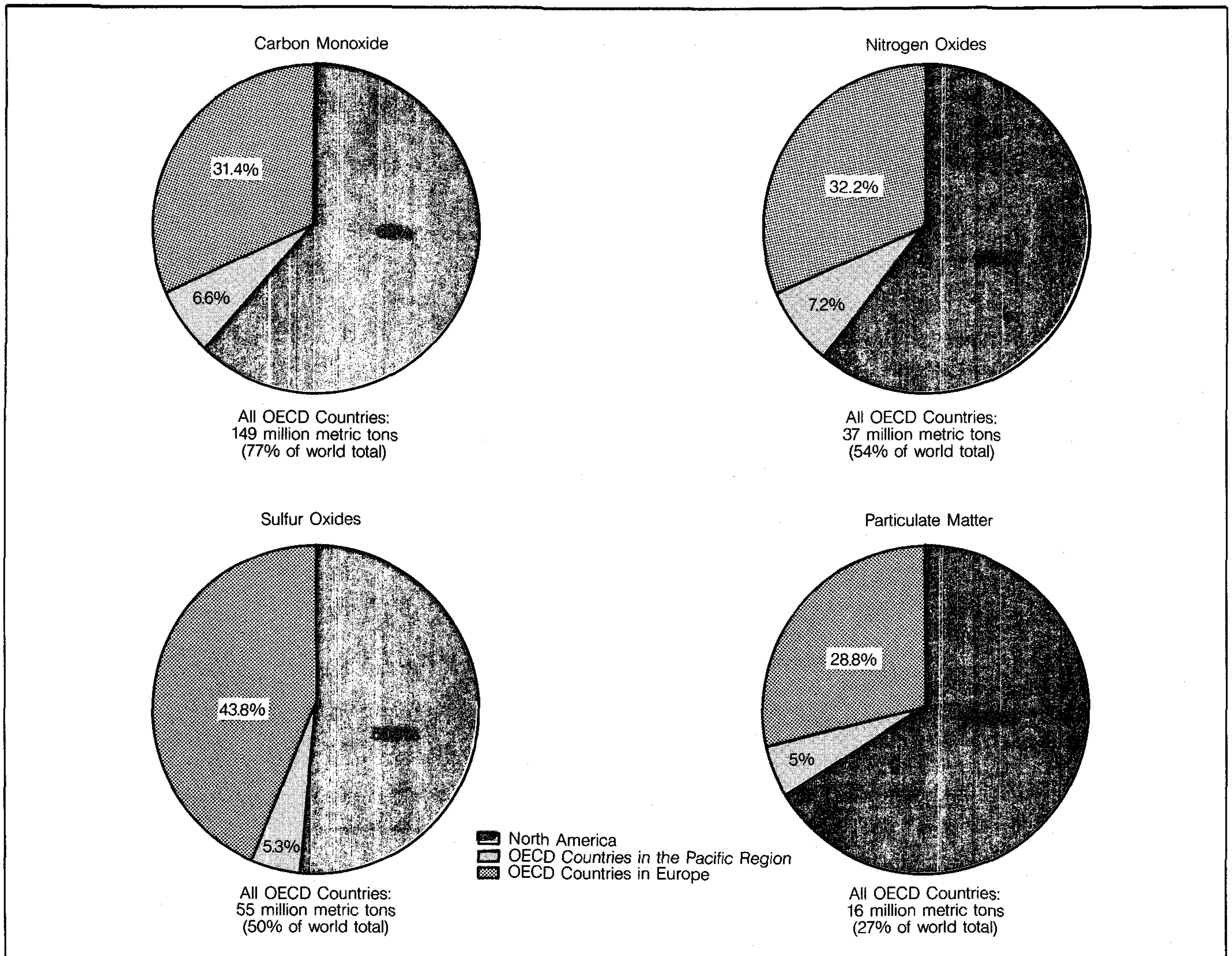
*Emission trends.* From 1970–79 in the OECD countries, $NO_x$ emissions from stationary sources remained relatively stable but increased in the transportation sector. However, for 1979–84, there has been an overall decrease (or stabilization) of $NO_x$ emissions in Japan, North America, and most of OECD Europe (except Southern Europe). In the Federal Republic of Germany, $NO_x$ emissions have increased by 55 percent in the past two decades. (See Figure 10.2.) The distribution of $NO_x$ emissions in major OECD regions is given in Figure 10.3, and the U.S. emissions estimates appear in Table 10.6.

Overall, emission trends reflect the increased volume of road traffic since the 1960s as well as the number of diesel cars. In the United States, however, the rate of increase in emissions has been dropping because of the controls placed on vehicle emissions since the mid-1970s: $NO_x$ increased 7 percent from 1970–83, with a 2 percent increase since 1975.

Only in Japan has there been a significant decrease in total $NO_x$: emission levels dropped by more than 90 percent, despite a dramatic increase over the past 20 years in the number of vehicles, especially passenger cars. This improvement is due to the fact that in the mid-1960s, Japan began to impose strong $NO_x$ emission controls on both mobile and stationary sources.

*Air quality trends.* Generally, trends in $NO_2$ air quality patterns are similar to estimated $NO_x$ emissions. For selected cities in the OECD network, ambient $NO_2$ levels remained relatively stable from 1975–79, except in London, where they actually decreased. Annual average concentrations increased in the United States from 1975–79 and then began decreasing; for 1979–83 $NO_x$ concentrations decreased by 15 percent.

**Figure 10.3 Emissions of Air Pollutants in Selected OECD Countries, 1980**




**Source:** Adapted from Organization for Economic Co-operation and Development (OECD), 1985, Reference 1, Compendium Table 2.1A.

**Table 10.4 Trends in Annual Averages of Sulfur Dioxide and Suspended Particulate Matter (SPM) at GEMS[a] sites, 1973–80**

| Site | No. of sites | Percentage of sites showing different trends: Downward[b] | Stationary | Upward[c] |
|---|---|---|---|---|
| **Sulfur Dioxide** | | | | |
| All sites | 63 | 54 | 30 | 16 |
| City center | 34 | 56 | 26 | 18 |
| Suburban | 29 | 52 | 34 | 14 |
| Commercial | 23 | 61 | 17 | 22 |
| Industrial | 20 | 55 | 30 | 15 |
| Residential | 20 | 45 | 45 | 10 |
| **Suspended Particulate Matter** | | | | |
| All sites | 62 | 43 | 47 | 10 |
| City center | 34 | 47 | 47 | 6 |
| Suburban | 28 | 39 | 46 | 15 |
| Commercial | 21 | 38 | 52 | 10 |
| Industrial | 20 | 50 | 40 | 10 |
| Residential | 21 | 42 | 48 | 10 |

**Notes:**
a. Global Environmental Monitoring System.
b. Downward is defined as a change of at least −3 percent.
c. Upward is defined as a change of +3 percent or more.
**Source:** World Health Organization (WHO), *Urban Air Pollution 1973-80* (United Nations Environment Program (UNEP/WHO, Geneva, 1984), p. 48.

### *Carbon Monoxide (CO)*

*Sources.* In most industrialized countries, local sources in urban areas are responsible for the relatively high ambient concentrations of carbon monoxide. The transportation sector contributes about 90 percent of all man-made CO emissions.

*Emission trends.* According to OECD data (24), total emissions decreased significantly from 1970–79 in North America and Japan, with mixed trends in Western Europe. An overall decline—or at least a stabilization—of CO emissions has continued since 1979 in the OECD countries. Figure 10.3 shows the distribution of CO emissions in 1980 from the major OECD regions; U.S. emissions from 1940–1983 are shown in Table 10.6.

Despite a continuing increase in vehicular traffic, CO emissions have decreased since 1975, mainly as a result of the auto emissions control programs, especially in Japan and the United States. In Japan, emission levels decreased by more than 50 percent between 1971 and 1981. In the United States, the trends show CO emissions decreasing by 31 percent from 1970–83; from 1975–83 the levels decreased by 16 percent.

*Air quality trends.* For OECD countries there has been a general decline or stabilization in the ambient level of carbon monoxide from 1975–79. The annual average concentrations in Japan peaked around 1960 and have been steadily declining since then. Between 1975 and 1983, the trend in the United States indicates a decrease of 33 percent, with little change from 1982–83 (25).

## PROBLEMS REMAIN

In spite of generally positive trends in OECD countries, many problems remain (26):

■ National ambient air quality standards as well as recommended concentration limits set by the WHO are still exceeded in many densely populated or industrial areas.

■ Many cities in developing countries, where pollution control programs are not well developed, are experiencing an overall decline in air quality as industrialization grows.

■ The health and environmental impacts of $NO_x$ may be greater than initially anticipated, particularly as they relate to the formation of ozone and their role in forest decline.

■ The control of fine particulate matter has not yet been satisfactorily accomplished.

■ Despite control efforts, ozone in the lower atmosphere has continued to increase, exacerbating related health and ecological effects.

■ Urban photochemical smog is emerging as a large-scale problem of international significance.

In addition to the problems related to these traditional pollutants, concerns are emerging about the emissions of "new pollutants." Of special concern is the increased

**Table 10.5 Trends in Sulphur Dioxide Concentrations in Urban Areas of Selected OECD[a] Countries, 1975–83[b]**

| | Category[d] | 1975 ($\mu g/m^3$) | $SO_2$ Index (base 100 in 1975)[c]: 1975 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| Canada | | | | | | | | |
| Montreal | A | 61 | 100 | 74 | 80 | 64 | 61 | X |
| United States | | | | | | | | |
| New York | A | 43.1 | 100 | 82 | 83 | 83 | 82 | 77 |
| Detroit | B | 38.1 | 100 | 83 | 68 | 77 | 76 | 67 |
| Japan | | | | | | | | |
| Tokyo | A | 60.2 | 100 | 81 | 80 | 71 | 70 | 49 |
| Kawasaki | B | 59.6 | 100 | 63 | 59 | 58 | 61 | 46 |
| Australia | | | | | | | | |
| Sydney | A | 39.0 | 100 | 103 | 97 | 93 | 81 | X |
| Newcastle | B | 33.0 | 100 | 58 | 88 | 84 | X | X |
| Belgium | | | | | | | | |
| Brussels | A | 99.0 | 100 | 73 | 63 | 53 | 45 | X |
| Liège | C | 85.0 | 100 | 80 | 92 | 74 | 74 | X |
| France | | | | | | | | |
| Paris | A | 115.0 | 100 | 90 | 77 | 62 | 59 | 53 |
| Rouen | B | 63.0 | 100 | 132 | 111 | 78 | 76 | 65 |
| Germany | | | | | | | | |
| Berlin | A | 95.0 | 100 | 111 | 96 | 81 | 86 | 71 |
| Ruhr Area | B | 161.0 | 100 | 80 | 60 | X | X | X |
| Italy | | | | | | | | |
| Rome | A | 62.0 | 100 | 162 | 121 | 140 | 143 | X |
| Milan | B | 244.0 | 100 | 111 | 76 | 73 | 52 | X |
| Luxembourg | C | 61.0 | 100 | 57 | 61 | 61 | 55 | 34 |
| Netherlands | | | | | | | | |
| Amsterdam | A | 34.0 | 100 | 100 | 74 | 76 | 62 | 59 |
| Rotterdam/Rijn | B | 52.0 | 100 | 92 | 75 | 81 | 69 | 71 |
| Norway | | | | | | | | |
| Oslo | A | 48.0 | 100 | 88 | 75 | 65 | 42 | 35 |
| Portugal | | | | | | | | |
| Barreiro/Seixal | B | 98.1 | 100 | 88 | 125 | 116 | 65 | 63 |
| Sweden | | | | | | | | |
| Gothenburg | A | 41.0 | 100 | 106 | 59 | 80 | 46 | 45 |
| United Kingdom | | | | | | | | |
| London | A | 123.0 | 100 | 80 | 82 | 67 | 61 | 49 |
| Newcastle | B | 115.0 | 100 | 81 | 80 | 57 | 51 | 35 |

X = not available
**Notes:**
a. Organization for Economic Co-operation and Development.
b. Methods of measurement are not strictly comparable among cities.
c. Annual average daily concentrations are given here as examples of general trends that have been confirmed in national reports and other sources.
d. Categories of cities: A. a city in which a notable portion (5-10 percent) of the national population is concentrated, B. industrial city in which a significant number of inhabitants are considered to have been exposed to a comparatively high level of pollutants in 1980, C. others; country network for Luxembourg.
**Source:** Organization for Economic Co-operation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), Table 2.2A.

**Table 10.6 Summary of National Emission Estimates in the United States, 1940–83**

| Year | Particulates (PM)[a] | Sulfur Oxides $(SO_x)$[a] | Nitrogen Oxides $(NO_x)$[a] | Volatile Organics (VOC)[a] | Carbon Monoxide (CO)[a] | Lead (Pb)[b] |
|---|---|---|---|---|---|---|
| 1940 | 22.4 | 18.0 | 6.7 | 17.7 | 79.4 | X |
| 1950 | 24.2 | 20.3 | 9.3 | 20.3 | 84.8 | X |
| 1960 | 20.9 | 20.0 | 12.8 | 23.3 | 87.5 | X |
| 1970 | 18.0 | 28.2 | 18.1 | 27.0 | 98.3 | 20.0 |
| 1971 | 16.7 | 26.8 | 18.5 | 26.3 | 96.3 | 22.0 |
| 1972 | 15.0 | 27.4 | 19.7 | 26.3 | 93.8 | 23.0 |
| 1973 | 13.9 | 28.7 | 20.2 | 25.7 | 89.5 | 202.7 |
| 1974 | 12.2 | 27.0 | 19.6 | 24.1 | 84.6 | 162.1 |
| 1975 | 10.3 | 25.6 | 19.1 | 22.7 | 80.5 | 147.0 |
| 1976 | 9.6 | 26.2 | 20.3 | 23.8 | 85.3 | 153.1 |
| 1977 | 9.0 | 26.3 | 20.9 | 23.6 | 81.1 | 141.2 |
| 1978 | 8.9 | 24.5 | 21.0 | 24.2 | 80.6 | 127.9 |
| 1979 | 8.8 | 24.5 | 21.1 | 23.5 | 77.4 | 108.7 |
| 1980 | 8.3 | 23.2 | 20.3 | 22.3 | 75.0 | 70.6 |
| 1981 | 7.7 | 22.3 | 20.5 | 21.0 | 72.3 | 55.9 |
| 1982 | 6.8 | 21.3 | 19.6 | 19.4 | 66.1 | 54.4 |
| 1983 | 6.9 | 20.8 | 19.4 | 19.9 | 67.6 | 46.9 |
| **Percent** | | | | | | |
| Change 1940–1983 | -69 | +16 | +190 | +12 | -15 | X |
| Change 1970–1983 | -62 | -26 | +7 | -26 | -31 | -77 |
| Change 1975–1983 | -33 | -19 | +2 | -12 | -16 | -68 |

X = not available
**Notes:**
a. Unit of measurement is teragrams/year ($10^6$ metric tons/year).
b. Unit of measurement is gigagrams/year ($10^3$ metric tons/year).
**Source:** U.S. Environmental Protection Agency (EPA), 1984, Reference 6.

number of unconventional trace pollutants in the atmosphere, such as toxic metals, fibers, and organic compounds. They may cause cancer, genetic changes, and birth deformities as well as engendering adverse ecological effects. In general, these substances are not routinely monitored and emissions are not well documented. More research and monitoring are needed in order to determine their levels in ambient air and their potential effects on human health.

## ACID DEPOSITION

Acid deposition is a major air quality issue in Europe and North America (27,28,29,30,31,32,33,34), and it may emerge as a significant problem in Asia. Many environmental effects have been attributed to "acid rain," including damage to lakes, streams, groundwater, forests, agriculture, buildings, statues, and human health.

"Acid rain" is a popular label for the complex scientific phenomena associated with atmospheric deposition. It is misleading, however, because acidic substances are not only deposited in rain, snow, fog, and dew, but they also fall from the atmosphere as dry particles.

The acid rain issue has undergone several significant changes in the last few years:

- Scientific and policy concerns have expanded beyond the threat of acidification of aquatic ecosystems. Observed changes in forests, in particular, have received increased attention.
- Although acid deposition is still seen as the primary atmospheric agent damaging aquatic ecosystems, many other air pollutants may also play a role in forest declines and materials damage.
- The geographic area now perceived as threatened by acid rain and the other air pollutants associated with atmospheric deposition has expanded far beyond Scandinavia and northeastern North America.

Because the emerging issue of multiple pollutants and forest decline is the subject of Chapter 12, this section focuses on the acidic component of atmospheric deposition and its relationship to aquatic ecosystems and the built environment.

### Transport of Atmospheric Pollutants

The atmosphere transports many air pollutants hundreds of kilometers before returning them to the earth's surface. During this long-distance transport, the atmosphere acts as a complex chemical reactor transforming the pollutants as they interact with other substances, moisture, and solar energy. Under the right conditions, emissions of sulfur dioxide and nitrogen oxides are transformed chemically during transport into sulfuric and nitric acids. In Northern Europe and eastern North America, about two thirds of the total atmospheric acidity is due to sulfur and one third to nitrogen (35). The ratio varies considerably with season and region, and in some areas, such as the western United States, it can be closer to 1:1.

Acid deposition takes both wet and dry forms. Typically, the dry forms (gases and particles) are found nearer their sources, and wet deposition occurs at longer distances (36). Estimates of dry deposition are uncertain because there is no satisfactory technique for measuring it directly. Nevertheless, the available data suggest that in

**Table 10.7 Trends in Concentrations of Suspended Particulate Matter in Urban Areas of Selected OECD Countries[a]**

| | Category[c] | 1975 (µg/m³) | Index, base 100 in 1975[b] 1975 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| **Canada** | | | | | | | | |
| Montreal | A | 103.0 | 100 | 69 | 76 | 62 | 53 | X |
| **United States** | | | | | | | | |
| New York | A | 50.4 | 100 | 99 | 102 | 97 | 89 | 86 |
| Chicago | B | 70.9 | 100 | 103 | 99 | 91 | 77 | 78 |
| **Japan** | | | | | | | | |
| Tokyo | A | 78.4 | 100 | 60 | 61 | 65 | 65 | 61 |
| **Australia** | | | | | | | | |
| Sydney | A | 112.0 | 100 | 72 | 78 | X | 65 | 68 |
| **Belgium** | | | | | | | | |
| Brussels | A | 32.0 | 100 | 69 | 59 | 63 | 50 | X |
| Antwerp | B | 30.0 | 100 | 83 | 43 | 60 | 47 | X |
| **France** | | | | | | | | |
| Paris | A | 57.0 | 100 | 105 | 89 | 88 | 82 | 81 |
| Nantes | C | 36.0 | 100 | 56 | 39 | 42 | 31 | 44 |
| **Germany** | | | | | | | | |
| Ruhr Area | B | 114.0 | 100 | 81 | 74 | 70 | 79 | X |
| **Luxembourg** | C | 37.0 | 100 | 57 | 46 | 46 | 41 | 27 |
| **Netherlands** | | | | | | | | |
| Amsterdam | A | 70.0 | 100 | 106 | 99 | 97 | 90 | 93 |
| Rotterdam/Rijn | B | 70.0 | 100 | 103 | 90 | 97 | 81 | 80 |
| **Norway** | | | | | | | | |
| Oslo | A | 32.0 | 100 | 61 | 84 | 103 | 81 | 84 |
| **Portugal** | | | | | | | | |
| Lisbon | A | 162.7 | 100 | X | 101 | 101 | 101 | 98 |
| **United Kingdom** | | | | | | | | |
| London | A | 36.0 | 100 | 64 | 53 | 58 | 50 | 61 |
| Stoke-on-Trent | B | 54.0 | 100 | 72 | 56 | 67 | 46 | 54 |

X = not available
**Notes:**
a. Methods of measurement are not strictly comparable among cities.
b. Categories of cities: A. a city in which a notable portion (5-10%) of the national population is concentrated; B. industrial city in which a significant number of inhabitants are considered to be exposed to a comparatively high level of pollutants in 1980; C. others; country network for Luxembourg.
c. Annual average daily concentrations are given here as examples to illustrate general trends which are confirmed in national reports and other sources.
**Source:** Organization of Economic Cooperation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), Table 2.2C.



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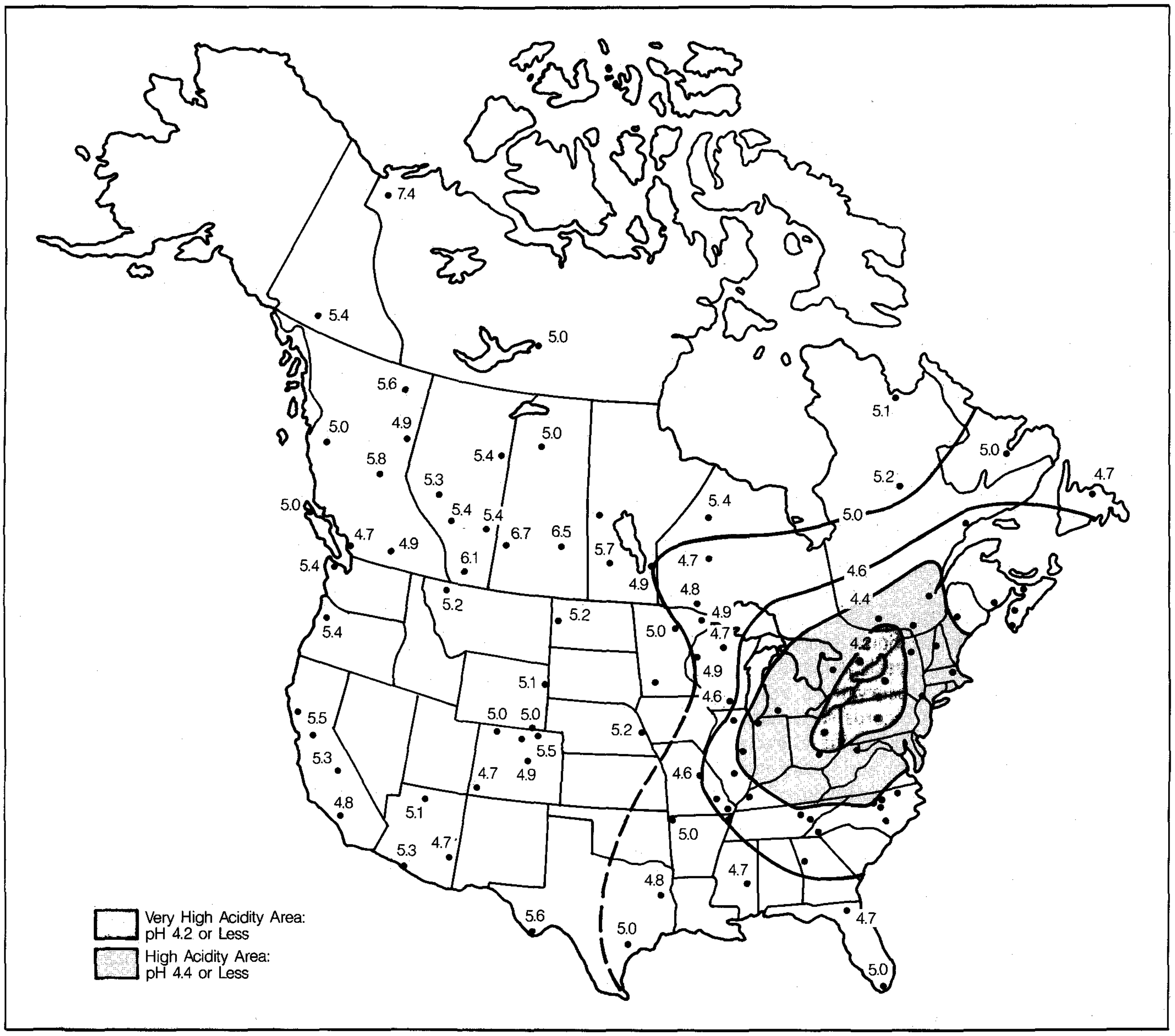
estimated to have a pH value below 5 with an additional 48,000 lakes (about 3 percent of the total) listed as being sensitive to acid deposition (65). Nine rivers in Nova Scotia have pH values below 4.7 and no longer support salmon or trout reproduction (66).

The most extensive survey of surface water chemistry ever conducted is currently underway as part of the U.S. National Acid Precipitation Assessment Program. Initial results from the U.S. National Surface Water Survey covering a statistically representative sampling of lakes in the eastern United States indicate that 10 percent of the lakes in the highly sensitive Adirondack region have pH values below 5 (67).

A similar high percentage was found in the Upper Peninsula of Michigan, but in other sensitive regions of the eastern United States, the average number of lakes below pH 5 was about 5 percent. In northern Florida, 12 percent of the lakes showed a pH below 5, which may

**Figure 10.7 Distribution of Acidity of Rain Over the United States and Canada, 1982**




**Notes:**
a. Map refers to wet deposition only. The pattern for dry deposition is likely to be similar.
b. Shaded areas indicate where high acidity (lower range of pH) occurs.
c. Dots are stations of a consortium of governmental and other institutions for acid-rain monitoring.
d. Numbers are pH readings at sample sites.
e. Lines show areas with approximately equal pH values.
**Source:** National Acid Precipitation Assessment Program (NAPAP), 1984, Reference 32.

be due to naturally occurring organic acids draining from major swamps in the region.

The U.S. National Surface Water Survey also found that a large proportion of the eastern lakes in sensitive regions had low acid neutralizing capacities (ANC). For the Adirondacks, 31 percent of the lakes had an ANC less than 40 microequivalents per liter and 70 percent had an ANC of less than 200 microequivalents per liter (200 is often considered the threshold of vulnerability to acid deposition). The ANCs of about 60 percent of the lakes in the other sensitive regions of the eastern United States are estimated at below 200 microequivalents per liter, as are the ANCs of 41 percent of the lakes in the southeast region located in sensitive areas (68).

### Cause and Effect Relationships

The relationship between acid deposition and surface water chemistry is complex. Most of the precipitation that eventually enters a lake has fallen on vegetation and run over or through soil before reaching the lake. During this journey, the acidity of the runoff can be modified by a factor of ten or more (i.e., more than 1 pH unit) (69). One result of this phenomenon is that although generally sensitive (low ANC) regions can be defined, the fate of any given body of water within them is determined by specific local factors.

Acidification causes many profound changes in aquatic ecosystems, affecting all trophic levels. The impact on fish is the most visible and thoroughly studied aspect of the problem. Fish reproduction and health are impaired not only by the toxicity of hydrogen ions but also by the toxicity of the metals mobilized by the increased acidity.

Aluminum (Al) poisoning is a major factor in reported fisheries declines and losses (70). As pH decreases, the toxicity of aluminum increases. At about pH 5, aluminum is most lethal to fish because it precipitates in their gills as aluminum hydroxide, reducing the oxygen content in the blood and causing salt imbalances in the fish. The problem is most acute where the organic content in the water is low, as is true of many acid-sensitive lakes. In naturally acidic "brown water" lakes, fish can tolerate a lower pH because the high organic content fixes or buffers the aluminum, making it less toxic (71).

Episodic fish kills observed in Europe and North America have usually been accompanied by acid "pulses" (72). These pulses of acidity can be caused by precipitation with very low pH values or by the rapid melting of snow during spring thaws. In either case, the volume and rapidity of the pulse can overwhelm the catchment's ability to neutralize or absorb the acid input so that the depressed pH values generate elevated levels of toxic metals. When the acid pulse is from spring snowmelt, it often occurs at the most vulnerable time in fish life cycles. Snow normally contains more nitrate than do summer rains, so the spring shock can exceed a system's ability to absorb nitrogen. In this way, nitrogen deposition can be more important in some fish kills than is suggested by its relative contribution to total acidity.

## DAMAGE TO THE BUILT ENVIRONMENT

Since the mid-19th Century, air pollution has been suspected of accelerating the degradation and corrosion of many types of materials, both natural and man-made. The most susceptible buildings, monuments, memorials, statues, cultural objects, and historical artifacts are located primarily in urban areas, where they are subjected to a host of pollutants. Damage from atmospheric deposition includes corrosion of metals, erosion and discoloration of paints, and deterioration of building stone (73).

Of course, materials that are exposed to the air are regularly subject to wind and solar radiation and a wide variety of other natural stresses, but structural deterioration is accelerated by pollution. In most cases the combined or additive effects of two or more agents causes more significant damage than any single pollutant (74,75,76).

The primary pollutants related to materials damage include sulfur dioxide, nitrogen oxides, ozone, and particulate matter. Because of its widespread distribution, $SO_2$ is considered the most significant for materials damage (77). The extent of damage to materials from acid deposition, as opposed to the other variables, is not known, and it is difficult to assess the relative contribution of dry-deposited versus wet-deposited substances.

Although the threat to cultural properties from pollution has been demonstrated in Europe, examples from the United States are not as convincing. In Europe, the number of intricately carved architectural surfaces and historical properties is much greater; the times of exposure are longer (centuries versus decades); the stone is often of poor quality; and the pollution levels are higher (78).

Overall, there has been a significant increase in damage to buildings and structures by air pollution in Europe, particularly since the 1950s, with the rapid growth of motor vehicle traffic (79). This trend in Europe coincides with the pattern of increasing levels of emissions and elevated concentrations of some air pollutants. Of primary concern is the extensive damage to stained glass windows, historically valuable natural stone buildings, and bronze memorials. (See Table 10.8.)

### Conclusion

The acid deposition issue is going through the transition from scientific pioneering to in-depth analysis of complex environmental phenomena. With the massive international research efforts now underway, the science of acid deposition is maturing. Indeed, more research was performed from 1982–86 than during the previous 20 years. New information means that policymakers now have a better understanding of the problems and can institute more effective controls, but there are no quick or easy solutions.

## POTENTIAL CHANGES IN STRATOSPHERIC OZONE

Ozone ($O_3$), a variant of oxygen ($O_2$), is present in minute amounts in the atmosphere. Ozone concentrations vary

## Table 10.8 Air Pollution Damage to Materials

| Material | Type of Damage | Other Principal Air Pollutants | Other Environmental Factors | Measurement Methods | Mitigation Measures |
|---|---|---|---|---|---|
| Metals | Corrosion, tarnishing | Sulfur oxides and other acid gases | Moisture, air, salt, particulate matter | Weight loss after removal of corrosion products, reduced physical strength, change in surface characteristics | Surface plating or coating, replacement with corrosion-resistant material, removal to controlled environment |
| Building Stone | Surface erosion, soiling, black crust formation | Sulfur oxides and other acid gases | Mechanical erosion, particulate matter, moisture, temperature fluctuations, salt, vibration, $CO_2$, microorganisms | Weight loss of sample, surface reflectivity, measurement of dimensional changes, chemical analysis | Cleaning, impregnation with resins, removal to controlled environment |
| Ceramics and Glass | Surface erosion, surface crust formation | Acid gases, especially fluoride-containing gases | Moisture | Loss in surface reflectivity and light transmission, change in thickness, chemical analysis | Protective coatings, replacement with more resistant material, removal to controlled environment |
| Paints and Organic Coatings | Surface erosion, discoloration, soiling | Sulfur oxides, hydrogen sulfide | Moisture, sunlight, ozone, particulate matter, mechanical erosion, microorganisms | Weight loss of exposed painted panels, surface reflectivity, thickness loss | Repainting, replacement with more resistant material |
| Paper | Embrittlement, discoloration | Sulfur oxides | Moisture, physical wear, acidic materials introduced in manufacture | Decreased folding endurance, pH change, molecular weight change, tensile strength | Synthetic coatings, storing, removal to controlled environment, deacidification, encapsulation, impregnation with organic polymers |
| Photographic Materials | Microblemishes | Sulfur oxides | Particulate matter, moisture | Visual and microscopic examination | Removal to controlled environment |
| Textiles | Reduced tensile strength, soiling | Sulfur and nitrogen oxides | Particulate matter, moisture, light, physical wear, washing | Reduced tensile strength, chemical analysis (e.g., molecular weight), surface reflectivity | Replacement with substitute materials, impregnation with polymers |
| Textile Dyes | Fading, color change | Nitrogen oxides | Ozone, light, temperature | Reflectance and color value measurements | Replacement with substitute materials, removal to controlled environment |
| Leather | Weakening, powdered surface | Sulfur oxides | Physical wear, residual acids introduced in manufacture | Loss in tensile strength, chemical analysis | Removal to a controlled atmosphere, consolidation with polymers, or replacement |
| Rubber | Cracking | Ozones | Ozone, sunlight, physical wear | Loss in elasticity and strength, measurement of crack frequency and depth | Addition of antioxidants to formulation, replacement with more resistant materials |

**Source:** J.E. Yocom and N.S. Baer, "Effects on Materials," in *The Acidic Deposition Phenomenon and its Effects*, Vol. 2, Critical Assessment Review Papers (U.S. Environmental Protection Agency, draft, Washington, D.C., 1983), pp. 7-1 to 7-49.

with altitude, but they are highest in the stratosphere (20–25 kilometers above the earth's surface). (See Figure 10.8.) Ozone in the troposphere, closest to the earth's surface, is a pollutant known to damage plants and to affect human health as well. However, stratospheric ozone plays a crucial role in shielding the earth's surface against ultraviolet radiation (UV) by absorbing wavelengths harmful to the health of people, plants, and animals.

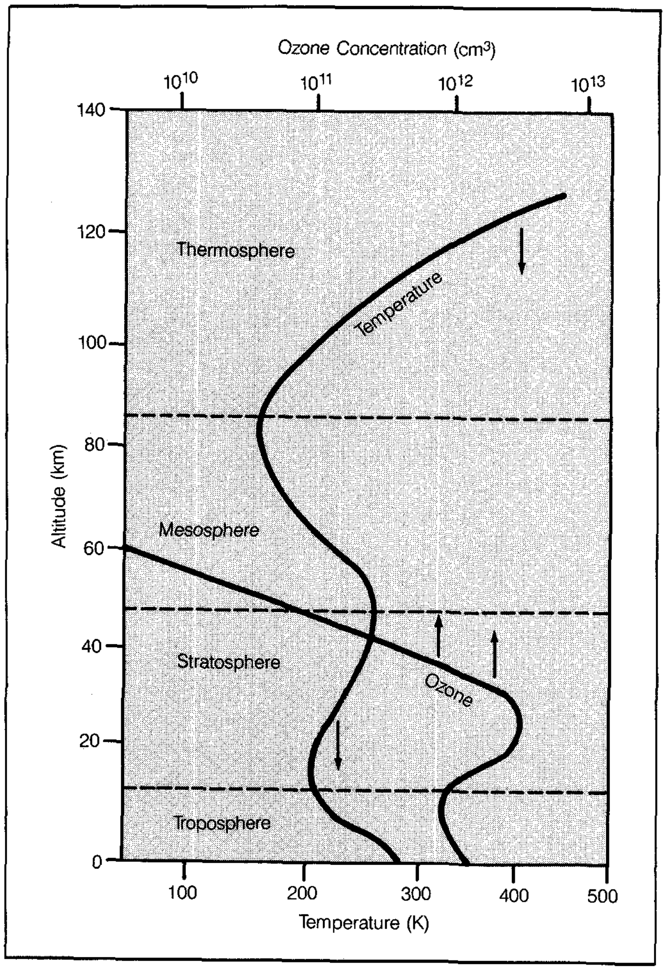
The concentrations of ozone at different altitudes are also critical to the radiative and meteorological processes that determine climate. The absorption of infrared radiation by ozone provides the main heat source for the stratosphere. Changes in stratospheric ozone would affect heating rates, air movements, and the downward emission of infrared radiation. Ozone in the lower stratosphere absorbs heat radiated from the earth; changes in its concentration would affect surface temperatures due to the greenhouse phenomenon. (See "Focus On: The Greenhouse Effect," below.) Changes in atmospheric temperatures could also affect water vapor concentrations thought to be important in climate formation (80,81).

Ozone concentrations are affected by catalytic reactions between the various forms of oxygen and nitrogen, chlorine, and hydrogen oxides. Small amounts (parts per billion) of these catalytic oxides control the actual amount of ozone (82). Human activities are changing the concentrations of these trace gases, and the changes, in turn, are expected to affect the concentration of ozone. A reduction in ozone would allow more UV to reach the earth's surface, and it could result in a range of consequences that have received only modest study (83).

The principal known effect of increased UV radiation on human health is an increase in non-melanoma skin cancers. The possibility of an increase in the rarer, frequently fatal, melanoma form of skin cancer is controversial (84). Other potential effects include suppression of human immunological systems (through effects on elements of the immune system in the skin or the formation of tumor antigens), damage to plants and animals (particularly some economically important species of cattle), and accelerated degradation of polymers. (See Table 10.9.)

The major source of concern to scientists has been a group of chemicals known as chlorofluorocarbons (CFCs), highly stable chemical compounds used in aerosol propellants, refrigeration, foam-blowing, and solvents. The consensus is that continuing emissions of CFCs at current levels would reduce the total amount of ozone by 3–5 percent in about 100 years (their atmospheric lifetime) (85). This small change in the ozone column is the net result of depletion of up to 60 percent of the ozone above 40 kilometers, much smaller reductions at 30 kilometers, and an offsetting increase at lower altitudes. Depletion may also be greater at high latitudes and at different seasons, leading to changes in lateral air movements and to greater increases in UV radiation (86).

**Figure 10.8 Temperature Profile and Ozone Distribution in the Atmosphere**




**Source:** National Aeronautics and Space Administration (NASA), 1984 Reference 80.

Modeling calculations of likely changes in stratospheric ozone are sensitive to assumptions about emission rates for CFCs, methane, carbon dioxide, and nitrous oxides. Models show methane and carbon dioxide emissions increasing stratospheric ozone, the former due to direct effects on atmospheric chemistry and the latter through indirect effects on atmospheric temperature and therefore reaction rates (87). Nitrous oxides decrease ozone, while the effect of nitrogen oxides (an airplane exhaust gas) is localized and varies with the altitude of injection. To further complicate matters, the effects are interdependent—the consequences of one chemical vary with the concentration of the others. According to some models, ozone destruction accelerates rapidly when the concentration of chlorine exceeds that of stratospheric odd-nitrogen ($NO_x$, $NO_2$, $HNO_3^-$, etc.).

Growth in CFC emissions seems likely but is difficult to forecast. Projections depend on assumptions about economic growth, the availability of substitutes, and possible new uses (88,89). In the last decade, substantial growth in non-aerosol uses (71 percent) corresponded to nearly comparable reductions in aerosols, but this balance may not continue.

Total CFC production data are not available because no figures have been released by the Soviet Union, Eastern Europe, and the People's Republic of China since 1975 (90). However, most of the world's production of CFCs is reported to the Chemical Manufacturers Association. Its data show increases of almost 8 percent in 1983 and over 7 percent in 1984; even aerosol propellant use increased in those years (91). Consumption in the United States (almost exclusively non-aerosol uses) increased over 10 percent per year in 1983 and 1984. International action to limit future growth of CFCs is currently under consideration. (See "Recent Developments," below.)

## FOCUS ON: THE GREENHOUSE EFFECT

The earth's climate is subject to various natural short-term deviations. Recent extreme examples of such anomalies are the drought in much of sub-Saharan Africa and the torrential rains in Ecuador and northwest Peru in late 1982 and early 1983 (92). In addition to these natural anomalies, there is a large and growing body of evidence suggesting that human activities are causing long-term changes in the earth's climate.

One important indicator of whether the climate is stable or is changing is the global mean surface temperature. An analysis of surface temperature data since the middle of the last century shows that both hemispheres experienced a general warming from the late 19th Century until about 1940 and a cooling until the mid-1960s. Since then, the world as a whole appears to have warmed. (See Figure 10.9.) Analyses of these observations suggest that the global mean temperature has increased 0.3°–0.7°C in the past 100 years. (See Box 10.1.)

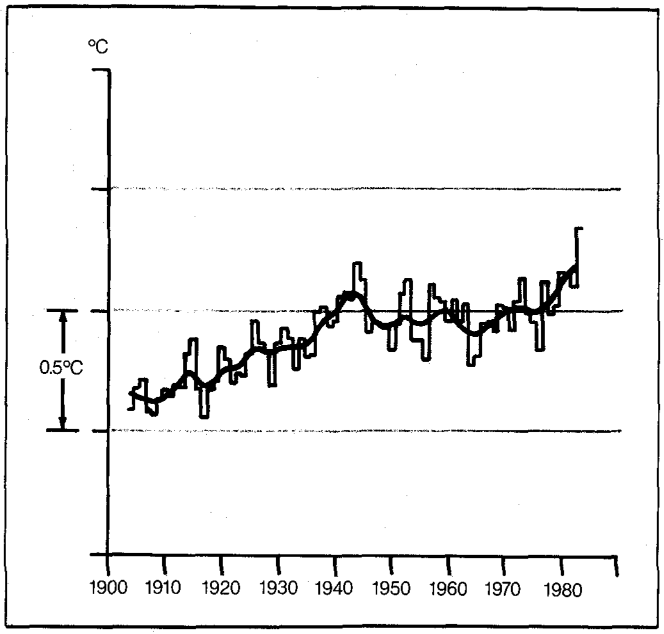
This trend in surface temperature could be due to natural factors alone, but there is reason to believe that it is at least partly due to human influences. Human activities are releasing increasing quantities of certain gases into the atmosphere that are thought to contribute to global warming. These gases are transparent to incoming short-wave radiation from the sun, but they absorb outgoing long-wave radiation. Consequently, increases in their atmospheric concentrations lead to a "greenhouse effect"—a warming of the Earth's surface and the lower atmosphere; for this reason, they are often called "greenhouse gases." Trends in the atmospheric concentrations of the most important of these gases are reviewed below.

**Table 10.9 Effects from Ozone Depletion**

| | Depletion Level | | |
|---|---|---|---|
| | 2.5% | 10% | 20% |
| Human Health Effects | | | |
| Non-Melanoma Cases | 470,000 per year | 1,890,000 per year | 3,770,000 per year |
| Melanoma Cases (Relationship not proven) | 15,000 per year | 65,000 per year | 146,000 per year |
| Suppression of Immune System | | no estimate now possible | |
| Degradation of Polymer Materials[a] | $175x10^6/yr | $2x10^9/yr | $6x10^9/yr |
| Eye cancer in Cattle | | no estimate now possible | |
| Effects on Plants | | no estimate now possible | |
| Effects on Aquatic Organisms | | no estimate now possible | |

**Note:** a. Rough approximations.
**Source:** U.S. Environmental Protection Agency (EPA), 1985, Reference 84.

**Figure 10.9 Variation with Time of the Global Mean Annual Surface Temperature, 1900–85**




**Note:** Data have been obtained from land and marine temperature records. The filtered curve has been obtained by suppressing variations on time scales of less than ten years.
**Source:** Bolin, in press, 1986, Reference 93.

## Atmospheric Carbon Dioxide Concentrations

The use of fossil fuels and the burning of biomass have increased the amount of carbon dioxide emitted into the atmosphere. Atmospheric concentrations of carbon dioxide have increased about 25 percent over the past 100 years from about 275 parts per million in the late 19th Century to 343 parts per million in 1984 (93). Further, observations at Mauna Loa, Hawaii, have clearly shown an accelerated trend in atmospheric $CO_2$ concentrations over the last three decades: from about 315 parts per million in 1958 to its current level of 343 parts per million (94). (See Figure 10.10.)

The estimated increase in the global mean temperature in the past 100 years is consistent with the observed increase in $CO_2$ and other greenhouse gases. Additional increases in $CO_2$ concentrations are expected to cause further warming. The most advanced experiments with general circulation models of the atmosphere-land-ocean system show that increases in $CO_2$ and other greenhouse gases, equivalent to a doubled atmospheric $CO_2$ concentration, would probably increase the global equilibrium surface temperature 1.5°–4.5°C.

Future trends in the atmospheric concentrations of $CO_2$ depend upon trends in fossil fuel use and emissions from the burning of biomass. At present, about 5 gigatons of carbon are emitted each year into the atmosphere through the combustion of fossil fuels. Although biotic emissions of carbon dioxide as a result of deforestation and land use changes have also contributed to the raised atmospheric carbon dioxide concentration in the past, it is clear that future emissions from biomass sources will be far smaller than those from fossil fuel combustion.

The $CO_2$ contribution from fossil fuel use will depend upon how energy demand evolves over time. As Chapter 7, "Energy," notes (see especially Figure 7.7), because there is a wide range of possible scenarios for future energy demand, there is a wide range of possible carbon dioxide emission rates. Rapid growth in energy and fossil fuel consumption could lead to a doubling of $CO_2$ (to over 600 parts per million) by about the year 2040; a low $CO_2$ emission scenario could postpone such a doubling until after the year 2100 (95).

## Trends for Other Greenhouse Gases

Carbon dioxide is not the only atmospheric constituent that is of importance to the heat budget of the atmosphere and, thus, the global temperature.

It has become apparent in the past few years that the combined contribution of other greenhouse gases to global warming and climate change is already about as important as that from $CO_2$. These gases are accelerating the rate of global warming arising from the greenhouse effect. Atmospheric concentrations of some of them (e.g., methane and certain chlorofluorocarbons) are increasing more rapidly than those for $CO_2$. The growing recognition of their importance is reflected in the fact that the title and scope of the Villach Conference were changed several months before it took place so that it covered these other greenhouse gases as well as $CO_2$. (See Box 10.1.)

### *Methane*

Methane is produced by microbes during the breakdown of organic carbon compounds under anaerobic conditions such as those found in waterlogged soils and in the intestines of ruminants. It is also released to the atmosphere when biomass is burned and during the production of coal and natural gas.

In recent years, the analysis of air trapped in glacial ice has made it possible to measure trends in atmospheric methane concentrations over long periods and with considerable accuracy. The methane concentration in Greenland ice containing air ranging from 50–27,000 years old is approximately 0.7 parts per million, which is only about half the present value (96). Methane concentrations began to increase about 300 years ago, but only within the past 20 years has the rapid change taken place (97,98). The atmospheric methane concentration has recently been increasing at a rate of 1–2 percent a year (99,100). There is still considerable uncertainty over the reasons for this increase, but possible causes are an increase in the number of domestic ruminants, more widespread cultivation of rice paddies, and biomass burning.

### *Chlorofluorocarbons*

A recent analysis of the role of chlorinated and/or fluorinated hydrocarbons in the radiative balance of the atmosphere showed that $CFCl_3$ (F11) and $CF_2Cl_2$ (F12) are

## Box 10.1. The Villach Conference

In October 1985, a conference was held at Villach, Austria, on greenhouse gases, climatic change, and associated impacts. The Villach conference was sponsored by UNEP, the World Meteorological Organization, and the International Council of Scientific Unions; it was the second in a series of five-year reviews. At the end of the conference, the following statement was issued outlining the current international consensus (1).

"The Conference reached the following conclusions and recommendations:

- "Many important economic and social decisions are being made today on major irrigation, hydropower, and other water projects; on drought and agricultural land use; on structural designs and coastal engineering projects; and on energy planning, all based on assumptions about climate. Most such decisions assume that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption. . .It is a matter of urgency to refine estimates of future climate conditions to improve these decisions.
- "Climate change and sea level rises due to greenhouse gases are closely linked with other major environmental issues, such as acid deposition and threats to the Earth's ozone shield, mostly due to changes in the composition of the atmosphere by human activity. Reduction of coal and oil use and energy conservation undertaken to reduce acid deposition will also lower concentrations of greenhouse gases; reduction in emissions of chlorofluorocarbons will help protect the ozone layer and will also slow the rate of climate changes.
- "While some warming of climate now appears inevitable due to past actions, the rate and degree of future warming could be profoundly affected by governmental policies on energy conservation, use of fossil fuels, and the emission of some greenhouse gases.

"These conclusions are based on the following consensus of current basic scientific understanding:

- "The amounts of some trace gases in the troposphere, notably carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), chlorofluorocarbons, and ozone, are increasing. . .
- "The role of greenhouse gases other than $CO_2$ in changing the climate is already about as important as that of $CO_2$. If present trends continue, atmospheric $CO_2$ and other greenhouse gases combined would be radiatively equivalent to a doubling of $CO_2$ from pre-industrial levels possibly as early as the 2030s.
- "The most advanced experiments with general circulation models of the climatic system show increases of the global mean equilibrium surface temperature for a doubling of the atmospheric $CO_2$ concentration, or the equivalent, of 1.5–4.5°C. . .
- "While other factors such as aerosol concentrations, changes in solar energy input, and changes in vegetation may also influence climate, the greenhouse gases are likely to be the most important cause of climatic changes over the next century.
- "Regional scale changes in climate have not yet been modelled with confidence. However, regional differences from the global averages show that warming may be greater in high latitudes during late autumn and winter than in the tropics, annual mean runoff may increase in high latitudes, and summer dryness may become more frequent over the continents at middle latitude in the Northern Hemisphere. In tropical regions, temperature increases are expected to be smaller than the average global rise, but the effects on ecosystems and humans could have far-reaching consequences. . .
- "It is estimated on the basis of observed changes since the beginning of this century, that global warming of 1.5°–4.5°C would lead to a sea level rise of 20–140 centimeters. A sea level rise in the upper portion of this range would have major direct effects on coastal areas and estuaries. A significant melting of the West Antarctic ice sheet leading to a much larger rise in sea level, although possible, is not expected during the next century.
- "Based on analyses of observations, the estimated increase in global mean temperature during the last 100 years of 0.3°–0.7°C is consistent with the observed increase in $CO_2$ and other greenhouse gases, although it cannot be ascribed in a scientifically rigorous manner to these factors alone.
- "Based on evidence of effects of past climatic changes, there is little doubt that a future change in climate on the order of magnitude obtained from climate models for a doubling of the atmospheric $CO_2$ concentration could have profound effects on global ecosystems, agriculture, water resources, and sea ice.

### RECOMMENDED ACTIONS

- "Governments and regional intergovernmental organizations should take into account the results of this assessment in their policies on social and economic development, environmental programs, and control of emissions of radiatively active gases.
- "Major uncertainties remain in predicting changes in global and regional precipitation and temperature patterns. Ecosystem responses are also imperfectly known. Nonetheless, the understanding of the greenhouse question is sufficiently developed that scientists and policymakers should begin an active collaboration to explore the effectiveness of alternative policies and adjustments. . .
- "Governments and funding agencies should increase research support and focus efforts on crucial unsolved problems related to greenhouse gases and climate change. . .Special emphasis should be placed on improved modeling of the ocean, cloud-radiation interactions, and land surface processes.
- "Support for the analysis of policy and economic options should be increased by governments and funding agencies. In these assessments, the widest possible range of social responses aimed at preventing or adapting to climate change should be identified, analyzed, and evaluated. . .Some of these analyses should be undertaken in a regional context to link available knowledge with economic decisionmaking and to characterize regional vulnerability and adaptability to climatic change. Candidate regions may include the Amazon Basin, the Indian subcontinent, Europe, the Arctic, the Zambezi Basin, and the North American Great Lakes."

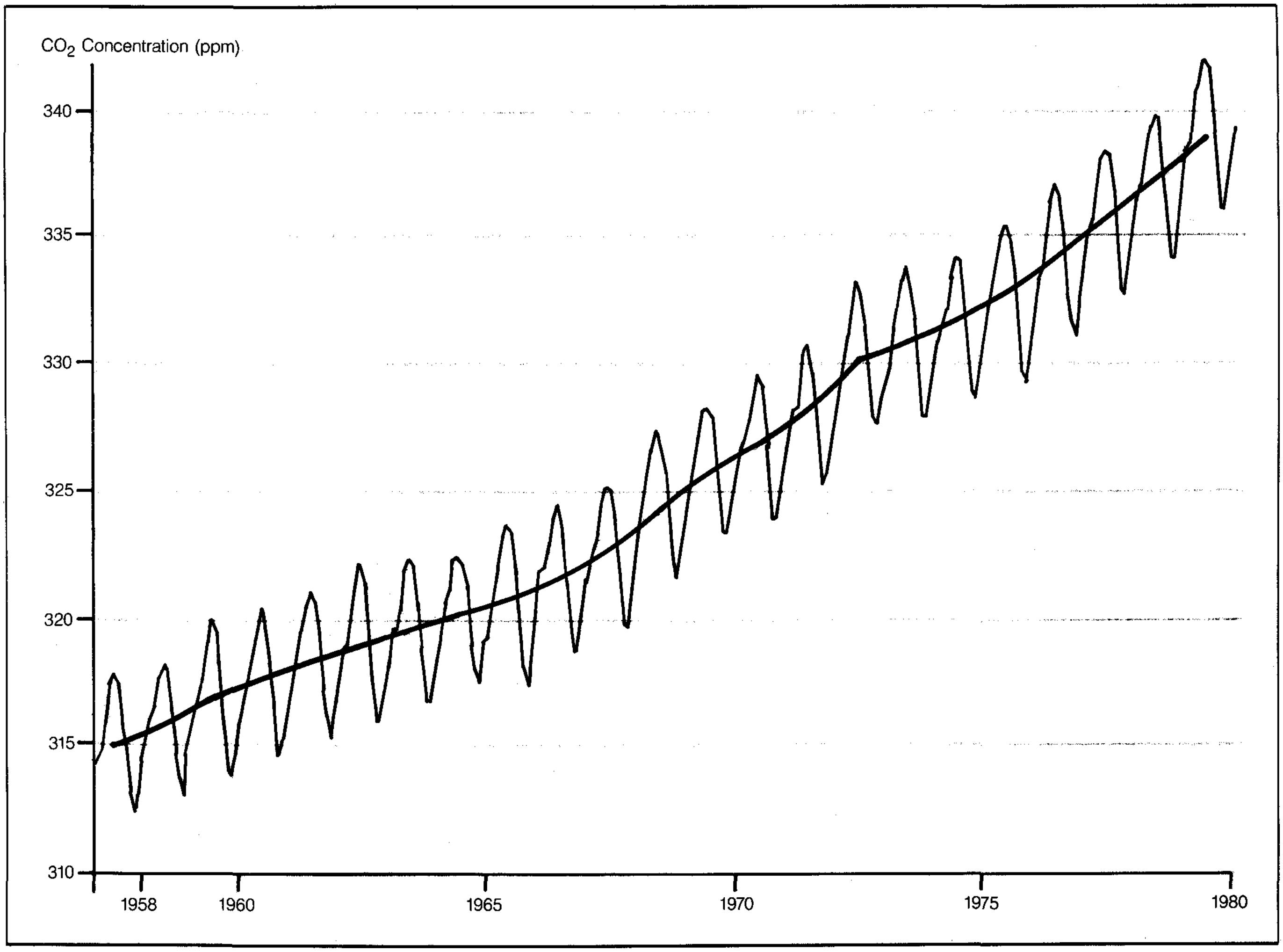
### References and Notes

1. United Nations Environment Program/World Meteorological Organization (WMO)/International Council of Scientific Unions, *An Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts* (WMO, Geneva, Switzerland, 1985).

the most important ones (101). At the beginning of 1980, the average concentration of F11 in the lower troposphere was estimated at 168 parts per trillion by volume, increasing at an annual rate of 5.7 percent (102). The F12 concentration was estimated at 285 parts per trillion by volume, with an annual increase of 6 percent (103).

Production of these gases for non-propellant uses has been increasing steadily (see "Potential Changes in Stratospheric Ozone," above), and if it continues to do so, CFCs' contribution to the greenhouse effect will be the second largest (after $CO_2$) during the first half of the next century.

**Figure 10.10 Mean Monthly Concentrations of Atmospheric $CO_2$ at Mauna Loa, 1958–80**




**Source:** National Research Council, 1983, Reference 120.
**Note:** The yearly oscillation is explained mainly by the annual cycle of photosynthesis and respiration of plants in the northern hemisphere.

### *Nitrous Oxide ($N_2O$)*

During the last few years, several studies have shown a steady increase in tropospheric $N_2O$ (104,105,106). This trend appears to be due primarily to rapidly increasing emissions from fertilizer applications and the combustion of biomass and fossil fuels (107).

Anthropogenic $N_2O$ emission rates are expected to increase less rapidly because of changes in fuel consumption trends and limitations on the total amount of land available for cultivation. (See Chapter 7, "Energy.") However, because $N_2O$ has a long atmospheric residence time (about 170 years), concentrations would continue to increase for several decades even if release rates were to remain constant. A 20–25 percent increase in $N_2O$ concentrations by the year 2030 was suggested recently (108,109).

### *Ozone*

Ozone concentrations vary considerably in both space and time as a result of atmospheric motion and chemical reactions. The lifetime of the ozone molecule in the troposphere is only a few weeks, making it difficult to identify long-term global trends in ozone concentrations. Despite these difficulties, it is now accepted that tropospheric ozone concentrations (near the earth's surface) are increasing due to photochemical processes. An increase has taken place at middle and high latitudes of the Northern Hemisphere during the last 2–3 decades: changes of 20–50 percent have been recorded and the present rate of increase seems to be 1–2 percent per year (110). Increases also seem to have occurred in the tropics, particularly in areas of extensive biomass burning.

The increase in ozone in the troposphere has been matched by a decrease in the stratosphere. Because about 90 percent of the ozone is found in the stratosphere, total ozone concentration trends primarily reflect changes at these higher levels. Therefore, overall ozone levels have been decreasing (111).

## The Effects of Climate Change

As well as leading to a general global warming of 1.5–4.5°C, a doubling of the atmospheric $CO_2$ concentration or the equivalent is expected to affect different parts of the world in different ways. Equatorial temperatures are thought likely to increase by about 50–100 percent of the average global warming. At the same time, average annual polar temperatures are likely to rise by two to three times the average global increase (112). There is also some evidence that mid-latitude, mid-continental drying during the summer (113) will occur, posing problems for agriculture in some developed nations. It is not yet possible to assess the regional impacts of the changing climate with any certainty, although many studies have been done on the type of impacts that could occur.

Agriculture tends to be acutely sensitive to climate. For example, in the United States the areas of optimal cereal production are narrowly defined. The western boundary of Corn Belt production is set by moisture requirements, especially by the need for a minimum of 20 inches of annual moisture. The southern boundary is defined by thermal considerations. On average, yields for corn decline 20 percent and 10–15 percent, respectively, with increases in regional temperature of 2°C and reductions in precipitation of 10 percent (114). Other crop yields, such as wheat, are similarly climate sensitive. Thus, U.S. agriculture might be significantly affected by a major greenhouse warming.

Agriculture in the developing countries would also be affected by changing climate. An average global warming of 4°C is expected to result in a 2.5–4°C increase in regional temperatures between 35° North latitude and 20° South latitude. There is some evidence that increases in tropical and subtropical temperatures would result in overall reductions in some crop yields (115). Food production in many developing countries has increased partly through the expansion of cultivation into the more marginal lands. This process may be increasing the sensitivity of agriculture to climatic change (116).

### Climate Change, Sea Level Rise, and Coastal Impacts

Since the turn of the century, the ocean surface temperature appears to have risen by $0.6 \pm 0.3$°C (117), a warming effect that correlates with the increase in the earth's surface temperature. Measurements of relative sea level at the same time suggest a global average rise of 1–3 millimeters per year (118). If the earth's atmosphere continues to warm, further rises in the global sea level are expected, due partly to the melting of land ice and partly to thermal expansion of the oceans' upper layer.

Large gaps and uncertainties in our understanding of oceans and glaciers make it difficult to predict the effects of further global warming on sea level. For example, knowledge of ocean circulation near and under Antarctic ice shelves is limited, and the models that are currently used for computation of thermal expansion generally do not incorporate the essential physics of deep-water formation and movement (119).

Because the uncertainties involved in estimating the effects of various factors on sea level between now and the year 2100 are large (assuming a doubling or thereabouts in the $CO_2$ concentration), predictions of the sea level rise vary considerably. One estimate is a rise of 70 centimeters over the next 100 years (120), another that a global rise of 144–217 centimeters by 2100 is most likely (121). Another more recent estimate is that a global warming of 1.5°–4.5°C would lead to a sea level rise of 20–140 centimeters. (See Box 10.1.)

An increase in the global sea level of one or two meters would significantly affect coastal activities. A rise of two meters would inundate some major coastal regions, parts of Louisiana and Florida in the United States (122), for example, and would flood many coastal beach resorts and marshes and low-lying flood plains along rivers and bays. A 0.3-meter rise would erode most sandy beaches along the U.S. Atlantic and Gulf coasts 30 meters inland and could destroy buildings, roads, and other structures and cause the intrusion of salt water into groundwater supplies (123).

It seems unlikely that even intensified research will make it possible to foresee the geographical patterns of a climatic change in significantly greater detail before clear signs of an ongoing change are apparent (124). But there is a consensus among scientists that the greenhouse effect is leading to major climatic changes. This view was reflected in the Villach Conference statement, which called for prompt initiation of policy studies by governments and international agencies in order to better assess the implications of a warmer climate and evaluate ways to anticipate, mitigate, or prevent climate change. (See Box 10.1.)

## RECENT DEVELOPMENTS

### INTERNATIONAL EFFORTS TO COMBAT ACID DEPOSITION AND TRANSBOUNDARY POLLUTION

The Organization for Economic Co-operation and Development and the U.N. Economic Commission for Europe have done much to bring about international consensus on the need to control emissions of sulfur and nitrogen, but the European Economic Community (EEC) is unique in its ability to impose binding directives on its member states (Belgium, the Netherlands, Luxembourg, West Germany, Denmark, France, the United Kingdom, Italy, Ireland, and Greece) by unanimous action. During the mid-1970s and early 1980s, the EEC imposed increasingly stringent standards on the sulfur content of fuels. The Commission of the European Community has recommended directives for its members that require the best available control technologies to be used in all new stationary sources of $SO_2$ emissions. The growing international commitment to action on the emission of acid precursors engendered a July 1985 directive implementing auto exhaust emissions standards designed to reduce sulfur and nitrogen oxide emissions by 60 percent. These reductions will be achieved through the phased introduction of catalytic converters on vehicles and increasing the use of unleaded petrol through 1993. (For a more thorough discussion, see Chapter 12, "Multiple Pollutants and Forest Decline.")

## VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER

On March 22, 1985, representatives of 20 nations concluded the first international environmental agreement providing an anticipatory response to an emerging problem (125). The Vienna Convention for the Protection of the Ozone Layer (126) is the first world-wide legal instrument directed to the protection of the atmosphere as a resource (127). The convention represents an important breakthrough for the United Nations Environment Program, which has acted as secretariat for government meetings on the ozone layer for almost a decade.

The exchange of information concerning production of chlorofluorocarbons is considered particularly significant, especially since the U.S. Chemical Manufacturers Association stopped reporting global production data several years ago because of the lack of reporting by the Soviet Union and Eastern Europe (128).

Despite extended efforts to include a protocol on control strategies, the convention does not do so (129). Two blocs of countries, the EEC and the Toronto Group (the United States, Canada, Finland, Norway, and Sweden), were unable to reach a compromise. The EEC proposed a limit on production capacity and a 30 percent reduction in unessential uses of CFCs, while the Toronto Group proposed more immediate and substantial reductions in aerosol uses coupled with a ceiling on per capita usage (130).

A resolution adopted by the parties to the convention provides for continued efforts by UNEP and a working group to conclude a protocol, and it authorizes UNEP to convene a Diplomatic Conference in 1987 for that purpose. The resolution calls on nations to control their CFC emissions "pending the entry into force of a protocol."

Another important result of the convention is the creation of a new permanent institution to oversee its implementation. Secretariat functions will initially be assumed by UNEP until the parties act. The convention will become effective upon ratification by 20 countries. Most countries that produce and use significant amounts of CFCs are expected to ratify, with the possible exception of Japan.

## NUCLEAR WINTER

During the first half of this decade, scientists identified for the first time a human influence on climate that appears to be more important than any other—nuclear war. In the 1970s, there were various assessments of the long-term global effects of nuclear war, notably that by the U.S. National Academy of Sciences (131), but none of these studies identified climatic change as a major consequence.

In 1980, scientists theorized that the mass extinction of species that occurred 65 million years ago could be attributed to the blocking out of sunlight by a dust cloud tossed into the atmosphere by the force of an asteroid striking the earth (132). A possible parallel between the dust-lofting effect of an asteroid and that of a sizable exchange of nuclear warheads was quickly recognized, encouraging a fresh look at the consequences of nuclear war (133). In 1982, Paul Crutzen from the Max Planck Institute for Chemistry and John Birks from the University of Colorado, Boulder, were the first to suggest that smoke and soot generated by large urban and forest fires might induce profound changes in weather. Their suggestions stimulated further research and appraisal world-wide (134). The possible effect of dust and sooty smoke on climate in the wake of a nuclear war is known as "nuclear winter" (135).

The nuclear winter hypothesis has been examined and refined considerably since it was first advanced (136). Misgivings and reservations about the findings were voiced, partly because they were so much at variance with conventional thinking, partly because they had profound implications for prevailing nuclear strategic policies, and partly because of the uncertainties and complexity of the underlying atmospheric physics (137). The principal scientific criticism was that the study by Richard Turco and others had used a simple one-dimensional model of the climate that ignored seasonal effects, cloud feedback, and the effects of atmospheric winds. Nevertheless, subsequent studies have confirmed that the potential exists for a major climatic disaster (138,139,140,141).

The latest and most thorough assessment of the climatic and associated biological effects of nuclear war was published in September 1985 by the Scientific Committee on Problems of the Environment (SCOPE) (142). The SCOPE report is based on a two-year study in which more than 300 scientists from 30 countries participated. According to the SCOPE scenario, 6,000 megatons of nuclear explosives (involving more than 12,000 warheads) would be detonated, injecting as much as 50–100 million metric tons of smoke into the atmosphere, 30 million of which would be light-absorbing carbon. The study concluded that the smoke would rise higher than previously thought. Much of the dust and soot would be driven into the stratosphere, where it would stabilize. Trapped above altitudes where precipitation occurs, the smoke would remain for months, and possibly more than a year. If the 30 million metric tons of carbon were to spread over the mid-latitudes of the Northern Hemisphere, the sunlight reaching the ground would be reduced by at least 90 percent. Smoke clouds over some areas would blot out all incoming sunlight.

Critics of the nuclear winter hypothesis have argued that as the atmosphere cooled beneath a smoke cloud, condensation processes would scavenge aerosols (143,144). The SCOPE report concludes, however, that condensation would not affect the upper levels of the aerosol layer and that the amount of water actually condensing would in any case be limited, so that not enough aerosols would be removed to prevent the nuclear winter effect (145).

Perhaps the SCOPE report's major finding is that the majority of the world population would be facing starvation in the aftermath of a nuclear war due to disruptions in agricultural productivity and/or food trade and aid. In Africa, for example, 100–450 million people could run out of food within the first 10 days of a war in which no nuclear weapons struck the continent. The study found that starvation and other indirect effects of a nuclear war could have a bigger impact on both combatant and non-combatant countries than the direct effects of blast, heat, and radiation.

Within the past four years, the nuclear winter concept has rapidly moved from being an interesting and novel idea to one that has been heavily scutinized and widely accepted by the international scientific community. Despite that, it has not yet influenced nuclear strategic thinking.

## References and Notes


1. Organization for Economic Co-operation and Development (OECD), *The State of the Environment 1985*, Chapter 1, Air (OECD, Paris, 1985).
2. United Nations Environment Program (UNEP)/World Health Organization (WHO), *Urban Air Pollution, 1973–1980* (Global Environmental Monitoring System, Geneva, 1984), p. 57.
3. *Ibid.* pp. 1–2.
4. B. Bennett *et al.*, "Urban Air Pollution Worldwide," *Environmental Science & Technology*, Vol. 19, No. 4, p. 298 (1985).
5. U.S. Environmental Protection Agency (EPA), *National Air Quality and Emission Trends Report, 1983* (EPA, Washington, D.C., 1985).
6. U.S. Environmental Protection Agency (EPA), *National Air Pollutant Emission Estimates, 1940–83* (EPA, Washington, D.C., 1984).
7. U.S. Environmental Protection Agency (EPA), *The Acidic Deposition Phenomenon and Its Effects, Critical Assessment Review Papers—Volume I* (EPA, Washington, D.C., 1983).
8. Japan Environment Agency, *Quality of the Environment in Japan—1982* (Environment Agency, Tokyo, 1983), pp. 166–214.
9. Tennessee Valley Authority (TVA), Electric Power Research Institute (EPRI), and Environmental Protection Agency (EPA), *Sulfur Oxides Control in Japan* (TVA, EPRI, and EPA, 1979), pp. 3–19.
10. Federal Republic of Germany, Federal Ministry for Research and Technology, *Environmental Research and Technology Program, 1984–87* (Bundesministerium fur Forschung und Technologie, Bonn, 1984).
11. V.A. Mohnen, Federal Ministry for Research and Technology, Federal Republic of Germany, 1985 (personal communication).
12. A downward trend is defined as a change of at least −3 percent; an upward trend is a +3 percent change.
13. *Op. cit.* 2, p. 47.
14. *Op. cit.* 1, *Compendium*, Table 2.2A.
15. In the literature, particulate matter is referred to as total suspended particulates (TSP) or suspended particulate matter (SPM). SPM is used here.
16. There are two chief methods for measuring suspended particulate matter—the smoke shade method and the gravitimetric (high volume) method; they may differ by a factor of 2 or 3. The SPM data collected by these two methods are reported separately. The gravimetric/high volume method is used in North America, parts of Europe, Asia, and Australia; the smoke concentration method in parts of Europe, South America, and New Zealand.
17. There can be a disparity between trends in emissions and in air quality. Emission estimates represent total particulate emissions (both large and small) without any distinction among particle sizes, but the large particles are more likely to settle out of the atmosphere and not be measured by air quality monitoring equipment used to measure suspended particulate matter.
18. *Op. cit.* 10.
19. *Op. cit.* 2.
20. *Op. cit.* 2, Annex 4.
21. *Op. cit.* 2, Annex 4.
22. *Op. cit.* 2, Annex 4.
23. *Op. cit.* 2, Annex 4.
24. *Op. cit.* 1.
25. CO monitoring sites are often located in traffic saturated areas and, therefore, reflect local air quality conditions. If the air quality levels at these locations improve, it is generally at a faster rate than the rate for nationwide reduction in emissions.
26. *Op. cit.* 1.
27. Organization for Economic Co-operation and Development (OECD), *The OECD Program on Long Range Transport of Air Pollutants* (OECD, Paris, 1977).
28. L.N. Overrein, *et al.*, *Acid Precipitation—Effects on Forest and Fish* (SFNS, Oslo, 1980).
29. Swedish Ministry of Agriculture, *Acidification Today and Tomorrow* (Ministry of Agriculture, Stockholm, 1982).
30. Environmental Resources Limited, *Acid Rain, A Review of the Phenomenon in the EEC and Europe* (Environmental Resources Ltd., London, 1983).
31. National Research Council (NRC), Committee on Physical Sciences, Mathematics and Resources, *Acid Deposition: Atmospheric Processes in Eastern North America* (NRC, Washington, D.C., 1983).
32. National Acid Precipitation Assessment Program (NAPAP), *Annual Report 1983 to the President and Congress* (NAPAP, Washington, D.C., 1984).
33. U.S. Environmental Protection Agency (EPA), *The Acidic Deposition Phenomenon and Its Effects* (EPA, Washington, D.C., 1984).
34. National Research Council (NRC), *Trends Related to Acid Deposition in North America* (NRC, Washington, D.C., in press, 1985).
35. *Op. cit.* 30 and 33.
36. *Op. cit.* 30.
37. *Op. cit.* 33.
38. P. Roth, *et al.*, *The American West's Acid Rain Test* (World Resources Institute, Washington, D.C., 1985), p. 8.
39. *Op. cit.* 30 and 33.
40. D. Whelpdale, "The Effects on Fishes of Acidic Deposition and Snow Melt Events," in *Proceedings of the Muskoka International Symposium on Acid Deposition* (Muskoka, Ontario, Canada, in press, 1985).
41. U.S. Congress, Office of Technology Assessment (OTA), *Acid Rain and Transported Air Pollutants: Implications for Public Policy* (OTA, Washington, D.C., 1984); and *op. cit.* 33.
42. *Op. cit.* 10.
43. *Op. cit.* 30 and 33.
44. R. Charlson and H. Rodhe, "Factors Controlling the Acidity of Natural Rainwater," *Nature*, Vol. 295, No. 5851, pp. 683–685 (1982).
45. J. Galloway, *et al.*, "Acid Precipitation: Natural versus Anthropogenic Components," *Science*, Vol. 226, No. 4676, pp. 829–831 (1984).
46. *Ibid.*
47. *Op. cit.* 30 and 33.
48. P.A. Mayewski, *et al.*, *A Detailed (1869–1984) Record of Sulfate and Nitrate Concentrations from South Greenland* (in press, 1985).
49. The European Air Chemistry Network (EACN) has been collecting and analyzing bulk precipitation samples for over 20 years at 50–120 sites in Western Europe. The EACN data provide a monitoring record of unequaled length, but some potential sources of error in the data exist. Problems that complicate interpretation include changes in analytical techniques around 1965 and the inherent limitations in bulk sampling such as contamination by extraneous matter not related to precipitation. Other European monitoring networks have substantially furthered our knowledge of deposition. The precipitation network set up under the Organization for Economic Co-operation and Development (OECD) Cooperative Technical Program in 1972 was perhaps the first specifically designed for studying acid rain. The current ECE European Monitoring and Evaluation Program has done much to standardize techniques to ensure data quality and comparability. The combined World Meteorological Organization (WMO)/U.N. Economic Commission of Europe (ECE)/U.N. Environment Program (UNEP) supported network consists of over 65 stations now operating in 20 nations.
50. A.S. Kallend, *et al.*, "Acidity of Rain in Europe," *Atmospheric Environment*, Vol.

17, No. 1, pp. 127–137 (1983).
51. *Ibid.*
52. G. Likens, *et al.*, "Variations in Precipitation and Streamwater Chemistry at the Hubbard Brook Experimental Forest during 1964 to 1977," in *Proceedings of the NATO Conference on Effects of Acid Precipitation on Vegetation and Soils* (Toronto, 1978).
53. *Op. cit.* 33.
54. P.W. Summers, *et al.*, "The Geographic Distribution and Temporal Variations of Acidic Deposition in Eastern North America," in *Proceedings of the Muskoka International Symposium* (Muskoka, Ontario, Canada, in press, 1985).
55. T. Okita, "Acid Precipitation and Related Phenomena in Japan," *Water Quality Bulletin*, Vol. 8, No. 2, pp. 101–108 (1983).
56. People's Republic of China, National Academy of Sciences, 1983 (personal communication).
57. *Op. cit.* 38, pp. 3–19.
58. *Op. cit.* 30.
59. *Op. cit.* 30.
60. *Op. cit.* 30.
61. *Op. cit.* 30.
62. J. Wieting, "Water Acidification by Air Pollutants in the Federal Republic of Germany," in *Proceedings of the Muskoka International Symposium* (Muskoka, Ontario, Canada, in press, 1985).
63. B.J. Mason, *The Current Status of Research on Acidification of Surface Waters* (The Royal Society of London, 1984).
64. R.S.E.W. Leuven, *et al.*, "The Impact of Acidification on Water Quality and Fish Communities of Poorly Buffered Waters," in *Proceedings of the Muskoka International Symposium* (Muskoka, Ontario, Canada, in press, 1985).
65. *Op. cit.* 31.
66. H.H. Harvey and C. Lee, "Historical Fisheries Changes Related to Surface Water pH Changes in Canada," in *Acid Rain/Fisheries* (American Fisheries Society, proceedings, 1982).
67. U.S. Environmental Protection Agency (EPA), *National Surface Water Survey* (EPA, Washington, D.C., 1985).
68. *Ibid.*
69. *Op. cit.* 34.
70. *Op. cit.* 29, p. 180.
71. *Op. cit.* 30.
72. *Op. cit.* 29, pp. 176–185.
73. *Op. cit.* 32.
74. D.R. Flinn, *et al.*, *Acidic Deposition and the Corrosion and Deterioration of Materials in the Atmosphere: A Bibliography (1880–1982)* (Environmental Protection Agency, Washington, D.C., 1983).
75. H. Schreiber, "Air Pollution Effects on Materials," in *Impact of Air Pollution on Materials* (Federal Environmental Agency, Federal Republic of Germany, NATO-CCMS, 1982).
76. Federal Republic of Germany, Federal Ministry of the Interior, *Report of the Causes and Prevention of Damage to Forests, Waters and Buildings by Air Pollution in the FRG*, Multilateral Conference on the Environment (Federal Ministry of the Interior, Munich, 1984).
77. *Op. cit.* 75.
78. Norbert Baer, 1985 (personal communication).
79. *Ibid.*
80. National Aeronautics and Space Administration (NASA), *Present State of Knowledge of the Upper Atmosphere: An Assessment Report* (NASA, Washington, D.C., 1984).
81. National Research Council (NRC), *Causes and Effects of Changes in Stratospheric Ozone: Update 1983* (NRC, Washington, D.C., 1984).
82. *Op. cit.* 80.
83. *Op. cit.* 81.
84. U.S. Environmental Protection Agency (EPA), *Analysis of Issues Concerning a CFC Protocol* (EPA, Washington, D.C., 1985).
85. *Op. cit.* 81.
86. *Op. cit.* 81.
87. NASA/WMO. *Atmospheric Ozone: Assessment of Our Understanding of the Processes Controlling its Present Distribution and Change,* Draft. (Washington/Geneva, 1986).
88. Organization for Economic Co-operation and Development (OECD), *Economic Aspects of CFC Emissions Scenarios* (OECD, Paris, 1983).
89. M. Gibbs and C. Trippe, *CFC Use and Emissions: Scenarios for the World through 2100* (EPA, Office of Policy Analysis, draft, Washington, D.C., February 1985).
90. Chemical Manufacturers Association (CMA), *Production, Sales and Calculated Release of CFC-11 and CFC-12 through 1984* (CMA, Washington, D.C., 1985).
91. *Ibid.*
92. World Meteorological Organization (WMO), *The Global Climate System: A Critical Review of the Climate System during 1982–1984* (WMO, Geneva, 1985), p. 7.
93. B. Bolin, *et al.*, *The Greenhouse Effect, Climatic Change, and Ecosystems: A Synthesis of Present Knowledge* (Scientific Committee on Problems of the Environment, forthcoming, Paris), Chapter 1.
94. *Ibid.*
95. *Ibid.*
96. H. Craig and C. Chou, *Geophysical Research Letters*, Vol. 9, p. 477 (1982).
97. R. Kerr, "Doubling of Atmospheric Methane Supported," *Science*, Vol. 226, pp. 954–955 (1984).
98. B. Stauffer, *et al.*, "Increase of Atmospheric Methane Recorded in Antarctic Ice Core," *Science*, Vol. 229, pp. 1386–1388 (1985).
99. *Op. cit.* 97.
100. *Op. cit.* 98.
101. V. Ramanathan, *et al.*, "Trace Gas Trends and Their Potential Role in Climate Change," *Journal of Geophysical Research*, Vol. 90, No. D3, pp. 5547–5566 (1985).
102. D. Cunnold, *et al.*, "The Atmospheric Lifetime Experiment 3. Lifetime Methodology and Application to Three Years of $CFCl_3$ Data," *Journal of Geophysical Research*, Vol. 88, pp. 8379–8400 (1983).
103. D. Cunnold, *et al.*, "The Atmospheric Lifetime Experiment 4. The Results for $CF_2Cl_2$ based on Three Years of Data," *Journal of Geophysical Research*, Vol. 88, pp. 8401–8414 (1983).
104. R. Weiss, "The Temporal and Spatial Distribution of Tropospheric Nitrous Oxide," *Journal of Geophysical Research*, Vol. 86, pp. 7185–7895 (1981).
105. M. Khalil and R. Rasmussen, "Increase and Seasonal Cycles of Nitrous Oxides in the Earth's Atmosphere," *Tellus*, Vol. 35, pp. 161–169 (1983).
106. J. Harriss and E. Nickerson, Eds., *Geophysical Monitoring for Climatic Change*, No. 12 (National Oceanic and Atmospheric Administration, Boulder, Colorado, 1984), p. 184.
107. H.J. Bolle, *et al.*, *Other Greenhouse Gases and Aerosols: Assessing their Role for Atmospheric Radiative Transfer* (Scientific Committee on Problems of the Environment, forthcoming, Paris), Chapter 4.
108. *Ibid.*
109. *Op. cit.* 101.
110. *Op. cit.* 107.
111. *Op. cit.* 107.
112. W.C. Clark *et al.*, "The Carbon Dioxide Question," *in Carbon Dioxide Review: 1982*, W.C. Clark, ed., (Clarendon Press, Oxford, 1982), p. 25.
113. *Op. cit.* 93.
114. D. Abrahamson and P. Ciborowski, "Harvest of Sand," *Amicus Journal*, p. 41 (Spring 1984).
115. P. Ciborowski, *The Greenhouse Problem. Physical Dimensions and Possible Impacts* (World Resources Institute, Washington, D.C., 1985), p. 12.
116. *Op. cit.* 93.
117. National Research Council, *Glaciers, Ice Sheets, and Sea Level: Effect of a $CO_2$-Induced Climatic Change* (U.S. Department of Energy, Washington, D.C., 1985).
118. *Ibid.*
119. *Op. cit.* 117, p. 2
120. National Research Council (NRC), Carbon Dioxide Assessment Committee, *Changing Climate* (NRC, Washington, D.C., 1983), p. 26.
121. U.S. Environmental Protection Agency (EPA), *Sea Level Rise Overview Paper* (EPA, Washington, D.C., 1983).
122. *Ibid.*
123. T. Hoffman, *et al.*, *Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100, and Research Needs* (U.S. Environmental Protection Agency, Washington, D.C., 1983), pp. 41–43.
124. *Op. cit.* 93, p. 28.
125. Signatories include Argentina, Belgium, Byelorussian SSR, Canada, Chile, Denmark, Egypt, Finland, France, Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Peru, Sweden, Switzerland, Ukranian SSR, the Soviet Union, and the United States. Mexico and Luxembourg signed on April 1 and 17, 1985 respectively.
126. U.N. Environment Program (UNEP), Vienna Convention for the Protection of

the Ozone Layer, Final Act (UNEP, Nairobi, 1985).
127. P. Sand, "Protecting the Ozone Layer: The Vienna Convention Is Adopted," *Environment*, Vol. 27, No. 5, pp. 19–20 and pp. 40–43 (1985).
128. Chemical Manufacturers Association (CMA), "Production, Sales, and Calculated Release of CFC-11 and CFC-12 through 1983," Appendix I (CMA, Washington, D.C., 1984).
129. U.N. Economic Commission for Europe (ECE), *Convention on Long-Distance Transboundary Air Pollution* (ECE, Geneva, 1979).
130. *Op. cit.* 84.
131. National Research Council, *Long-Term Worldwide Effects of Multiple Nuclear Weapons Detonations* (National Academy of Sciences, Washington, D.C., 1975).
132. L. Alvarez, *et al.*, "Extraterrestrial Cause for the Cretaceous-Tertiary Extinction," *Science*, Vol. 208, pp. 1095–1108 (1980).
133. National Research Council, *The Effects on the Atmosphere of a Major Nuclear Exchange* (National Academy Press, Washington, D.C., 1985), p. 186.
134. P. Crutzen and J. Birks, "The Atmosphere after a Nuclear War: Twilight at Noon," *AMBIO*, Vol. 11, pp. 114–125 (1982).
135. This term was originally coined by Richard Turco, coauthor of Reference 136.
136. R. Turco, *et al.*, "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," *Science*, Vol. 222, No. 4630, pp. 1283–1292 (1983). The biological consequences of the atmospheric analysis done by R. Turco, *et al.* have been widely publicized by biological scientists working in conjunction with R. Turco, *et al.* This group of scientists wrote a companion article: P. Ehrlich, *et al.*, "Long-Term Biological Consequences of Nuclear War," *Science*, Vol. 222, No. 4630, pp. 1293–1300 (1983).
137. C. Sagan, "Nuclear Winter: A Report from the World Scientific Community," *Environment*, Vol. 227, No. 8, p. 12 (1985).
138. *Op. cit.* 134.
139. The Royal Society of Canada (RSC), *Nuclear Winter and Associated Effects* (RSC, Ottawa, 1985).
140. U.S. Department of Defense (DOD), *The Potential Effects of Nuclear War on the Climate: A Report to the U.S. Congress* (DOD, Washington, D.C., 1985).
141. Scientific Committee on Problems of the Environment, *Environmental Consequences of Nuclear War: SCOPE 28* (John Wiley and Sons, Chichester and New York, 1985).
142. *Ibid.*
143. E. Teller, "Widespread After-Effects of Nuclear War," *Nature*, Vol. 310, pp. 621–624 (1984).
144. J. Katz, "Atmospheric Humidity in the Nuclear Winter," *Nature*, Vol. 311, p. 417 (1985).
145. *Op. cit.* 141, pp. 132–133.

# 11. Policies and Institutions

Are the world's institutions up to the management tasks suggested by the preceding chapters? Is there sufficient expertise, money, and political will to protect fragile ecosystems like the tropical forests, manage highly stressed environments like the semi-arid crop and range lands of Africa, provide essential services for rapidly expanding populations, and regulate pollutants that travel thousands of kilometers across many national boundaries? Are policies and the means to execute them keeping up with the environmental challenges of today's generation and the next? These are big and important questions. This chapter presents some answers, albeit preliminary and partial ones given the scope of the subject and space limitations.

## SETTING THE STAGE

Awareness of human impact on the natural environment has grown rapidly over the past two decades. It has been manifest in countless conferences, meetings, publications, and debates. Many have taken an intelligent guess at what the future holds and have reacted with alarm; many more with numbed complacency. Still others have accused those who point out adverse trends of alarmism or pseudoscience (1). There is no consensus.

Forming a considered evaluation of institutional progress is made even more difficult by the scale and geographical scope of the issues. In 1982, a report entitled "Economic and Ecological Interdependence" (2) by the Organization for Economic Co-operation and Development (OECD) pointed out that the growing interdependence of the international economic and political system had become a central concern. This interdependence is seen to cover not only population, migration, energy, food, financial transfers, and technology, but also the environment and, increasingly, the ecological basis for economic activity. "Understanding of this interdependence and its implications can lead to hope or despair," the report concluded, "depending on one's view of the will and capacity of Governments to make necessary adjustments within and among their countries."

Political will can be strongly affected by public opinion, which is not easy to pin down. Although the state of the environment is not typically an issue that wins or loses elections, opinion polls conducted in the developed countries show that the long-term condition of the planet and, in turn, the quality of life on it are of surprisingly significant public concern (3). (See Figure 11.1.) And to judge from the number of organizations courting such opinion, the politics of the environment are stronger than ever.

Despite all the activity, it is easy to mistake the degree of real progress from inside the environmental community. People intimately involved with a set of issues so loudly debated and discussed necessarily think everyone else is concerned. There is also a new difficulty in choosing priorities. In the world of fundraising for crisis



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system, but will present its report, *Common Future*, to the General Assembly in 1987. Significantly, 14 of the Commission's 22 members are from developing countries. According to Gro Harlem Brundtland, its chairman, the group intends to:

- Re-examine the critical issues of environment and development, and formulate innovative, concrete, and realistic action proposals to deal with them;
- Assess and propose new forms of international co-operation on environment and development that can break out of existing patterns and influence policies and events in the direction of needed change; and
- Raise the level of understanding and commitment to action on the part of individuals, voluntary organizations, businesses, institutions, and governments (14).

Not all governments welcome the Commission. Some fear the pressures that may be generated for new initiatives; others are skeptical about putting the world to rights through the thoughts of a worthy few. Nevertheless, the Commission's *raison d'être* was due, at least in part, to the U.N. system's failure to change the worst of environmental deterioration since the Stockholm conference. Most important, it is a route by which governments can shift ground toward a more interdependent world view should they wish.

From the outset the Commission's agenda has differed from the standard agenda of environmental and natural resource issues. It places the interdependence of states at center stage, in terms of transboundary pollution, transboundary management needs, common property resources (e.g., genetic diversity, the oceans, and the atmosphere) and, not least, economic activity. The "new" agenda joins issues across the traditional sectoral lines. It identifies "energy, environment and development"; "food security, agriculture, forestry and environment"; and "international economic relations, environment and development" as integrated subjects (15). Though not truly novel, the Commission's "new" agenda represents an unusual attempt at the intergovernmental level to link environmental disruption to its major causes: *bad* development or *no* development at all. In effect, the Commission's agenda restates the view that those who promote an environmental ethic are not "antigrowth," but instead are solidly based in the business of economic development.

## The World Conservation Strategy, 1980

Many traditional wildlife conservationists made their first contact with the broader environmental agenda in 1980 with the drafting of the World Conservation Strategy (WCS). Its impact continues to be felt, helping bring about the new approach toward sustainable development. The United Nations Environment Program commissioned the International Union for Conservation of Nature and Natural Resources (IUCN) to prepare the Strategy and joined with the World Wildlife Fund in supporting its preparation.

The WCS was first and foremost an attempt to bring conservation and development together: "Human activities are progressively reducing the planet's life-supporting capacity at a time when rising human numbers and consumption are making increasingly heavy demands on it. The combined destructive impacts of a poor majority struggling to stay alive and an affluent minority consuming most of the world's resources are undermining the very means by which all people can survive and flourish" (16). To some people, the emphasis upon man's, as opposed to nature's, needs was out of balance. But that is not the point. The conservation lobby, once so strongly associated with wildlife protection, had come of age. In effect, it was saying: "we want a better style of development—sustainable development—because that is the only way to achieve conservation."

The task of drafting was in itself a remarkable feat of consultation and review across a vast range of international opinion and expertise. The result, in summary, is simple and straightforward:

1. It explains the contribution of living resource conservation to human survival and to sustainable development,
2. It identifies priority conservation issues and the main requirements for dealing with them, and
3. It proposes effective ways of achieving the strategy's goals.

The attempts by IUCN to have national conservation strategies prepared the world over is a continuing program (17). In many cases it is stimulating the integrative approach to the environment in previously barren administrations. By November 1985 about 40 countries were preparing or had prepared national or sub-national conservation strategies (18). (See Part IV, "Policies and Institutions," Table 12.2.) A critical review of progress made and changes needed will take place in 1986 at an international conference in Ottawa.

## The World Industry Conference on Environmental Management, 1984

Business leaders tend to be realists when it comes to assessing the potential for economic growth. A small but growing number realizes that, especially in the Third World, the cycle of poverty and natural resource degradation can be broken only by creative management of both economic growth and resource conservation.

Industry, en masse, blessed the current consensus at the first World Industry Conference on Environmental Management (WICEM), convened at Versailles by UNEP and the International Chamber of Commerce (ICC) in late 1984. Some 300 participants were expected, but more than 500 attended, representing 71 countries.

The meeting produced 15 broad recommendations grounded in five principles on the environment and development that repeat the often-heard ideals. Sustainable economic development was mentioned along with environmental management, planning cycles, cost benefit analysis, anticipatory policies, and other measures (19). WICEM's 15 recommendations, if taken seriously by industry, could dramatically improve how commerce and the environment can be reconciled.

Unlike many other conventions, WICEM did not lead to a new institution to implement its agreements. Rather, the co-sponsors, UNEP and ICC, agreed to strengthen or modify their own structures to accommodate the fruits of this collaboration.

Shortly after attending WICEM, Maurice Strong, Secretary General of the 1972 Stockholm Conference and a businessman and policymaker on international environment and development issues, urged environmental activists "to establish closer links and better understanding with business and industry as well as with governments and inter-governmental organizations." Business and industry are "the principal agents through which environmental correction and prevention must take place," he said. "And they are increasingly sensitive and responsive to these needs. Industry has become far more environmentally oriented than many in the environmental community have yet been prepared to recognize" (20). In the developed countries environmentalists are beginning to drop their confrontational attitudes toward industry in favor of a cooperative approach. In the United States, for example, groups comprised of representatives of industry and environmental organizations have undertaken to formulate joint policy on a range of issues from pesticide policy to hazardous waste disposal. And while relatively few business leaders fully share Strong's views, many corporations, large and small, have made important positive strides.

## The Global Meeting on Environment and Development for NGOs, 1985

In February 1985, the Environment Liaison Center (ELC), with support from UNEP, convened the Global Meeting on Environment and Development for Non-Governmental Organizations (NGOs) at its Nairobi headquarters.

Reflecting the growing confidence of the worldwide NGO community, the meeting brought together for the first time the leaders of more than 100 citizens groups, voluntary organizations, and other private groups from 48 countries to discuss common issues in environment and development. A broad spectrum of environmental, development, relief, population, and religious organizations was represented (21).

Anil Agarwal, chairman of the ELC, struck the theme: "what we face today is nothing less than the failure of the development process, the development paradigm, that we have been so avidly running after. . . Finding and implementing a new development process, an equitable and sustainable development process, is the biggest intellectual and political challenge we face"(22).

The conference participants answered this challenge not with a final declaration (which they feared might smother the diversity of cultures, values, and models of sustainable development represented there), but with a commitment to actively pursue 119 proposals stressing citizen participation and the role of NGOs. Needed actions were identified in more than a dozen different fields, including the traditional sectors (e.g., agriculture, forests, water, and energy) and several cross-cutting areas (e.g., development assistance, appropriate technology, international debt, and impact of militarization).

The meeting also highlighted the need for a two-pronged approach involving both "macro" and "micro" levels. Macro issues concern broad policy questions and lend themselves to lobbying governments and international agencies through the media, membership efforts, and leadership education. These approaches are quite distinct from strengthening grass roots capabilities to, for example, manage community forestry projects at the micro level. Both approaches were combined in a "No More Bhopals" network launched at the meeting.

This gathering may have sparked a new phase of NGO cooperation that could improve NGO effectiveness both in national capitals and in their communities.

## Three Essential Capacities

Many of the hundreds of recommendations offered by *these six recent initiatives require three essential* capacities, principally at the national level:

1. That countries actually know the status and trends of their natural resources and environment—assessments are available.
2. That they can make and execute environmental policy—they have the capacity to manage.
3. That their environmental and resource management programs operate in a supportive larger context—international cooperation, external financial assistance, public support and participation, and a helpful attitude in the business community all contribute.

Most developing countries are weak on all three counts. The developed countries tend to be much more diverse. Some still know very little about the actual state of their resources, for example, though they may possess strong management capacities.

The next sections deal separately with the tools available for progress on each broad front. As with the political initiatives just discussed, we do not attempt to cover everything. In a description of the most recent highlights, much of importance has had to be omitted.

## ASSESSMENT

Accurate data on demographic and resource conditions and trends are the first prerequisite to sound policy. In the environmental field, as this volume demonstrates over and over again, the availability of adequate data can by no means be taken for granted. The next necessity is the ability to assess both the baseline information and the pluses and minuses of alternative projects and policies. In this respect, also, many countries' capacities are terribly weak.

### Collecting Data

In the 1970s, data collection focused on pollution. But even in this field, progress has been slow. Basic information on the extent and consequences of air and water pollution is still lacking for much of the world. Moreover, the meaning of the mass of data that is available is limited by large gaps in knowledge that have come to light from many fields of research.

Also in the 1970s, the first large-scale regional programs were undertaken to measure pollutants of common concern. For example, around the Mediterranean Sea more than 80 institutions are today engaged in a cooperative program of research and monitoring that has survived the political vicissitudes of the area. The resulting assessments have led to regional conventions and national activities to reduce pollutant flows into the shared sea. This regional program has been replicated in a dozen similar "Regional Seas" programs serving some 120 coastal states (23).

New pollution problems continue to emerge—such as the recent indications of widespread contamination of groundwater—for which severe analytical problems remain to be overcome. But, by and large, the procedures for measuring and monitoring pollutants and for taking them into account in national planning and decision making are now reasonably well understood. They can be applied where there is the will.

On the other hand, accurate measurement and monitoring of many forms of resource degradation (e.g., deforestation, desertification, soil erosion, salinization, and waterlogging) are variously spotty, unreliable, or still impossible. The tools to accurately locate and measure natural resources are confined mostly to *non*-renewable resources, such as minerals, and oil and gas, for which there is a strong commercial motivation.

As recently as 1982, UNEP's authoritative "The World Environment—1972–1982" concluded that: "There are general local and/or regional figures for the extent of deserts, rangelands, farmlands, and other major land-use categories, but detailed information about their conditions—and rates of degradation—are rarely available" (24).

The opportunity for improved assessment of these natural resources rests heavily on the development of airborne and satellite sensors that measure signal strength from the earth's surface in various spectral frequencies and convey these data in digital form. Unlike the chemical emulsion plates on which high-altitude "pictures" used to be based, such data are now transmitted and recorded on magnetic tape as signals that can be converted into images, much like those on television screens, though far more detailed.

The availability of such data has forced the development of machines and software that can align remote sensing data with the ground elements to which the data correspond. Called Geographical Information Systems (GIS), this technology can present an image that geographically corresponds to a given area, and can realign other data points to the same area, even if acquired at different times, from different sensors. Although these techniques have obvious application for military and intelligence uses, the requirement of the U.S. National Aeronautics and Space Act of 1958 that "activities in space should be devoted to peaceful purposes for the benefit of all mankind" has meant that the results of the U.S. National Aeronautics and Space Administration's (NASA) extensive data collection, and the techniques it has developed for interpretation of the data, have been placed in the public domain.

In 1985 the first formal transfer of this capability to an international organization took place when The Global Resource Information Database (GRID) was dedicated in Geneva by UNEP and the Swiss government. GRID consists of the machines and the software developed by NASA and made available to UNEP and the U.N. system to analyze data collected by these international organizations (25).

GRID's immediate application will be to integrate and improve the analysis of various data sets already built up by UNEP's Global Environmental Monitoring System (GEMS) program, with data sets from the World Health Organization, the Food and Agriculture Organization, the World Meteorological Organization, and others. If the program works as intended, dramatically improved assessments of the planet's environmental trends can be carried out and kept up to date (26).

The GRID facility will also be a training site, helping to transfer digital analysis skills to the national level, where they are generally absent. Although the hardware and software at GRID in Geneva represent an investment of many millions of dollars, the growing capacities and declining costs of microcomputers put the capability to carry out such analysis within reach of any university, and make it an attractive area for donor agencies to support.

Already, work underway at the World Bank uses data generated by GRID to analyze soil, vegetation cover, and meteorological conditions in some African countries as a prelude to finding new ways to increase local food production on a sustainable basis. This process can be greatly accelerated in future years as countries develop their own means to carry out such analyses in more detail. Ultimately, perhaps, such data and the skills to interpret them may become routinely available even at the local level.

## National and Sectoral Assessments

The first complaint of policymakers and politicians, when confronting a new problem, is that they do not have enough information for making decisions, and, more often than not, they are correct. Until recently, few countries took stock of their environmental conditions and trends except as they related to specific activities such as mining, forestry, irrigation, or energy production. But with the growing sensitivity of governments to environmental issues and the increasing number of international agreements dealing with resources, the need for both national and international data on the environment has been dramatized repeatedly.

Before the Stockholm Conference, only Japan and the United States compiled comprehensive national reports on their environmental conditions; both began doing so in 1970, although many others had sectoral reviews. Since then, national state-of-the-environment reports have been published by: France in 1978; Belgium in 1979; Yugoslavia in 1980; India in 1982; the Philippines and Sweden in 1983; Malaysia in 1984; and Finland, Chile, Ireland, and Poland in 1985. Country state-of-the-environment reports are being drafted in Burkina Faso, Sudan, Saudi Arabia, and Canada. (See Part IV, "Policies and Institutions," Table 12.2.)

Many other countries, such as the United Kingdom, rely on standing committees or commissions to periodically review key aspects of national environmental policy.

State-of-the-environment reports, environmental profiles, and national conservation strategies are all variations on the national assessment theme. They are prepared by governments, agencies, or non-governmental organizations.

The two editions of *The State of India's Environment* (1982 and 1985) provide an excellent example of the latter. Prepared by the Centre for Science and the Environment in New Delhi (27), the reports attempt to cover the gamut of India's vast and complex environment, drawing on official and non-governmental data alike. The advantages of an independent assessment are that it can evaluate both business and government policies, and can point out information gaps—things governments are often reluctant to do. In this case, the reports have dealt with such touchy subjects as the loss of common property resources for the poor, and corruption or abuse of the country's natural resource stock by various agencies, domestic and foreign.

General assessments of a country's environmental condition are, without question, a key step toward building public awareness and fostering sound decision making. But such overall assessments are generally not directly useful for management purposes. They often fail to bring enough focus or detail together on particular sectors to satisfy the specialist, the relationship between sectors is often unclear, and the prescriptive elements of the reports are weak. Furthermore, the data are often fragmented and inconsistent.

Related to the preparation of national overviews is the growing tendency of international assistance agencies to call for general environmental appraisals and specific sector reviews where environmental policies are seen to be significant (e.g., in forestry, land use, and renewable energy). The World Bank, the U.S. Agency for International Development (U.S. AID), the European Economic Community (EEC), and other multilateral and bilateral agencies are commissioning environmental reviews of one sort or another. There is great variation in the type, focus, and level of detail of these efforts, and a clear need for some coordination of all this activity through an open international referral system.

An innovative and valuable effort to assess the state of the environment at the international level is now published annually in the United States. *State of the World*, prepared by the Worldwatch Institute, attempts to measure progress in "the extent to which our economic and social systems are successfully adjusting to changes in the underlying natural resource base." It examines issues as diverse as "reducing dependence on oil," "maintaining world fisheries," and "managing rangelands" (28).

## Project Assessments

There is also an expanding library of project-specific environmental assessments, which has ballooned since the U.S. National Environmental Policy Act initiated the technique of formal environmental impact assessment (EIA) in 1970. The variations on the theme are legion, as each country or sector has devised a model best suited to its own purposes. A parallel library of reviews and analyses of the process itself has also grown up.

The most comprehensive review of the EIA process as a tool for development in the Third World was prepared for the International Union for Conservation of Nature and Natural Resources (29). Called *Status and Application of Environmental Impact Assessment*, this valuable document sets out the basic methods, experience, and benefits of the EIA process to date and presents a series of recommendations for its use in situations where the administration and basic data are weak. The study shows that EIA procedures are now used extensively by external funding sources as well as by some Third World countries themselves. This review will be updated in 1986 when the results of a joint exercise on the appropriate use of EIAs in development projects by the environmental and development assistance committees of OECD are published.

Underlying the process of environmental impact assessment is an attempt to bypass intuition and to construct a more formal approach to decision making. That is, of course, the purpose of much of planning law, which has a tradition going back decades. An EIA, if well done, has two particular strengths: it forces an integration of natural science with economic evaluation, and it lays out the options considered and—often more important—those *not* considered by the policymaker. On the other hand, nearly all project-specific assessments are carried out late in the planning process and are therefore often seen as a hindrance rather than a useful contribution to good decision making.

For good or ill, much EIA activity in developing countries takes place as a result of, or with the assistance of, external agencies. For instance, few countries in Africa have a formal mechanism for injecting environmental factors into project planning. But this is not universally true. Most members of the Association of Southeast Asian Nations (ASEAN) do have formal EIA policies (30) and have accumulated considerable experience with them.

## Improving Assessments

In addition to environmental impact assessment, other methodologies are now being used to bridge the gap between environmental management and development practice, including rapid rural appraisals (31), land capability analysis (32), and more. Perhaps the most important area of progress is in the development of more sophisticated alternatives to traditional cost-benefit analysis; that is, developing methodologies that can express economic, environmental, and ecological change in a common unit of measurement, and within a single planning process or procedure.

In some cases, these new approaches involve modifying the practice of traditional economic assessment. One successful method, called "natural systems assessment with economic valuation," has been formalized and tested enough to have been adopted by the Asian Development Bank (33). Its authors consider that the system has five special features:

1. "Consideration of sustainable use and environmental quality at the earliest stages of project inception;

## Box 11.1 Lessons of the Global Models

Predicting the future from current conditions and trends is inevitably risky. For example, the very act of defining a trend often causes policy changes, and these cannot be anticipated. However, in the 1970s, the emerging capacity of computers to handle masses of data led to the flowering of an international school of global modelers. Prominent among the global models were:

- The Forest/Meadows model: Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States.
- The Mesarovic/Pestel models: Systems Research Center, Case Western Reserve University, Cleveland, Ohio, United States; and Technical University, Hannover, West Germany.
- The Bariloche model: Fundacion Bariloche, San Carlos de Bariloche, Rio Negro, Argentina.
- The MOIRA (Mode of International Relations in Agriculture) model: Economic and Social Institute, Free University, Amsterdam, Netherlands; and Agricultural University, Wageningen, Netherlands.
- The SARU model: Systems Analysis Research Unit, Department of the Environment, London, United Kingdom.
- The FUGI model: Engineering Research Institute, Faculty of Engineering, Tokyo University, Tokyo, Japan.
- The United Nations World model: Economic Research Center, New York University, New York, United States; and Brandeis University, Waltham, Massachusetts, United States (1).

An analysis of these models concluded that despite strong differences in approach and methodology, 12 common "messages" could be drawn about the state of the world and its possible futures.

1. "There is no known physical or technical reason why basic needs cannot be supplied for all the world's people into the foreseeable future. These needs are not being met now because of social and political structures, values, norms, and world views, not because of absolute physical scarcities.
2. "Population and physical (material) capital cannot grow forever on a finite planet.
3. "There is no reliable, complete information about the degree to which the earth's physical environment can absorb and meet the needs of further growth in population and capital. There is a great deal of particular information, which optimists read optimistically and pessimists read pessimistically.
4. "Continuing business-as-usual policies through the next few decades will not lead to a desirable future—or even to meeting basic human needs; it will result in an increasing gap between the rich and the poor, problems with resource availability and environmental destruction, and worsening economic conditions for most people.
5. "Because of these difficulties, continuing current trends is not a likely future course. Over the next three decades the world socio-economic system will be in a period of transition to some state that will be, not only quantitatively but also qualitatively, different from the present.
6. "The exact nature of this future state, and whether it will be better or worse than the present, is not predetermined, but is a function of decisions and changes being made now.
7. "Owing to the momentum inherent in the world's physical and social processes, policy changes made soon are likely to have more impact with less effort than the same set of changes made later. By the time a problem is obvious to everyone, it is often too far advanced to be solved.
8. "Although technical changes are expected and needed, no set of purely technical changes tested in any of the models was sufficient in itself to bring about a desirable future. Restructuring social, economic, and political systems was much more effective.
9. "The interdependence among people and nations over time and space are greater than commonly imagined. Actions taken at one time and on one part of the globe have far-reaching consequences that are impossible to predict intuitively, and probably also impossible to predict (totally, precisely, maybe at all) with computer models.
10. "Because of these interdependencies, single, simple measures intended to reach narrowly defined goals are likely to be counterproductive. Decisions should be made within the broadest possible context, across space, time, and areas of knowledge.
11. "Cooperative approaches to achieving individual or national goals often turn out to be more beneficial in the long run to all parties than competitive approaches.
12. "Many plans, programs, and agreements, particularly complex international ones, are based upon assumptions about the world that are either mutually inconsistent or inconsistent with physical reality. Much time and effort is spent designing and debating policies that are, in fact, simply impossible" (2).

### References and Notes


1. D. Meadows, *et al.*, *Groping in the Dark—The First Decade of Global Modelling* (John Wiley and Sons, Chichester, 1982), p. 20.
2. *Ibid.*, p. xviii.


2. "Integration of the assessment into both the economic appraisal and the economic planning organization rather than its treatment as a separate, externally generated document added at a later stage;
3. "Quantification and monetization to the fullest extent possible;
4. "Continuous monitoring of indicator parameters for feedback into adaptive management; and
5. "Post-project review to judge the accuracy of predictions and the extent to which mitigative measures were implemented" (34).

While a definite improvement on common practice, this system remains weak in dealing with the monetization of many important parameters (such as esthetic values, human mortality, the services of undisturbed ecosystems, etc.) and in the quantification of costs and benefits that occur in the mid- to long-term (i.e., it proposes no alternative to traditional discounting). But, as in many other instances illustrated in this volume, the system's greatest weakness is that much of what the careful decisionmaker *needs* to know, is unknown. (See Table 11.1 for one example.)

In a different approach, UNEP is working on changing the calculation of national accounts: a key form of economic assessment. The motivation for the change is the imbalance codified in the present international system of drawing up these accounts, namely that man-made assets are valued as productive capital while natural resources are not. Thus, while man-made assets are depreciated, natural resources are not. "As a result," says one economist, "a country could exhaust its mineral resources, cut down its forests, erode its soils, and hunt its wildlife and fisheries to extinction, but measured income would rise steadily as these assets disappeared" (35).

To correct this asymmetry, economists are attempting to devise methods to broaden national income accounts. In this way they hope to adequately account for the depletion of natural resource stocks, the effects of pollution, and other environmental variables in a country's assessment of its economic development. The United

Nations Enviroment Program and the World Bank have sponsored international workshops in 1983, 1984, and 1985. From these exercises it is apparent that "in most countries it would be more appropriate to emphasize separate environmental accounts for subsequent linkage with GNP accounting, that considerable data already exists,... and that the most important resources and environmental services to be accounted for and the appropriate levels of aggregation would vary from country to country in accordance with environmental, technological, and social factors" (36). Norway provides an advanced example of natural resource accounting in practice with its long-term program 1986–89 (37).

## MANAGEMENT: THE CAPACITY FOR ACTION

A government's ability to move from understanding the condition of its resources to the creation of policy, and from there to the execution of that policy, depends principally on its stability and political legitimacy, and on the availability of funds and adequate human and technical resources. Such general characteristics apply, of course, to all policy and can really be appraised only on a country by country basis.

Narrowing the focus to resource and environmental policy makes the task of evaluating management capacity only a trifle easier. It does, however, highlight a steadily expanding network of instruments and institutions that has grown up over the past three decades. The number, scope, and complexity of these agencies, laws, treaties, guidelines, and the like have increased dramatically during the past 15 years. Yet, they by no means tell the whole story: The best laws in the world mean little in a country unable to apply them; an environmental agency that looks fine on paper will make little difference if its representative is not at the table when decisions are made; and an international agreement honored principally in the breach will change reality very little. Nonetheless these tools provide a sound index of overall trends—certainly management *without* them is impossible in modern societies—and can be used to review in broad outline the capacity for resource management around the world.

### National Environmental Agencies

The number of national environmental management agencies skyrocketed in the decade after the 1972 U.N. Conference on the Human Environment in Stockholm. At the time of this conference, 25 countries, 11 of them in the developing world, had environmental management agencies. Today, more than 140 countries, including 110 developing countries, have them (38), and a listing of the principal agencies runs to several hundred pages (39).

The creation of an agency is one thing; its effectiveness quite another. In developed and developing countries alike, environmental agencies have been plagued by the lack of human, technical, and financial resources and have been very much junior members within the circle of government ministries. Often, heads of these agencies operate at the mid-level, without access to decision-makers at the top. Beyond that, monitoring and enforcement vary widely from close control to none at all.

As government debts have grown, especially in the past few years, environmental agencies and priorities have lost money and influence—sometimes disproportionately (40). OECD closely reviews management trends in its member states, and in 1987 its Vienna Center plans to publish a comprehensive comparison of 14 Eastern and Western European countries. No doubt this report will confirm OECD's earlier assessment that even among these wealthy nations "several countries were unable to devote the resources to environmental programs that were required" (41).

### Legislation and Policy

The 1970s were also marked by a rush of environmental and resource-related legislation, especially in the industrial countries. (See Table 11.2.) Within the past few years, the stream of legislation has slowed in the industrial countries, and the emphasis has shifted to implementing the laws already on the books, making changes for greater efficiency or consistency with other programs, and carrying out the necessary research and monitoring (42).

Generalizations about the state of environmental legislation and policy in the developing countries are bound to be crude, since conditions vary widely and few surveys exist (43). In many parts of the developing world, the 1970s were at first a period of antipathy toward, and then gradual acceptance of, the notion that environmental issues are a valid concern. In 1985, Julius Nyerere of Tanzania spoke for many countries inside and outside of Africa when he said, "Until the last few years, Africa regarded environmental concern as an American and

**Table 11.1 Discounted Present Value of Costs of Geothermal Wastewater Disposal Under Alternative Schemes in the Philippines**
*(millions of pesos)*

| Alternative Options | Direct Costs | Estimated Environmental Costs | Total Measured Costs | Nonquantified or Nonquantifiable Costs |
|---|---|---|---|---|
| 1. Reinjection | 138.3 | Unknown | 138.3 | Energy loss |
| 2. Untreated discharge into Mahiao River | 120.2 | Rice: 7.3 Fisheries: 56.5 | 184.0 | Freshwater fishery, stock health, laundry, bathing uses, human health, sea ecosystems |
| 3. Treated discharge into Mahiao River | 359.3 | No Estimate Made | 359.3 | Rice production, lower loss on items in option 2 with the exception of sea ecosystems |
| 4. Untreated discharge into Bao River | 81.1 | Fisheries: 56.5 | 137.6 | Freshwater fishery, stock health, domestic use, human health, sea ecosystems |
| 5. Treated discharge into Bao River | 359.1 | No Estimate Made | 359.1 | Less than option 4 |
| 6. Piping into ocean at Lao Point | 243.1 | Unknown | 243.1 | Nonquantifiable but high |
| 7. Piping into ocean at Biasong Point | 353.2 | Unknown | 353.2 | Nonquantifiable but high |

**Source:** R.A. Carpenter and J.A. Dixon, 1985, Reference 33, p. 29.

## Table 11.2 Major National Environmental Laws in OECD Countries, 1956–84[a]

| | Type of Law | | | | | |
|---|---|---|---|---|---|---|
| | General | Water | Wastes | Air | Impact Statement | Other |
| Canada | | 1970 | | | 1973 | 1975[b] |
| United States | 1970 | 1972 | 1965 | 1963 | 1969 | 1976[b] |
| | | 1977 | 1970 | 1970 | | |
| | | | 1976 | 1977 | | |
| | | | 1984 | | | |
| Japan | 1967 | 1958 | 1970 | 1962 | | 1973[b] |
| | 1970 | 1970 | | 1968 | | 1973[c] |
| Australia | 1974 | | | | 1974 | |
| New Zealand | | 1967 | | 1972 | 1972 | |
| | | 1974 | | | 1977 | |
| Austria | | 1959 | | | | 1973 |
| Belgium | | 1971 | 1974 | 1964 | | |
| Denmark | 1973 | 1978 | 1978 | | | 1978[d] |
| | | 1980 | | | | 1979[b] |
| | | 1982 | | | | |
| Finland | | 1961 | 1978 | 1982 | | 1923[d] |
| | | 1979 | | | | 1965[e] |
| France | 1976 | 1964 | 1975 | 1974 | 1976 | 1977[b] |
| Germany, Federal Republic of | | 1957 | 1972 | 1974 | 1975 | 1976[d] |
| | | 1976 | | | | |
| Greece | 1976 | 1977 | | 1983 | | 1977[f] |
| | 1980 | 1978 | | | | 1985[g] |
| Iceland | | | | | | |
| Ireland | 1976 | 1977 | | 1977 | 1976 | |
| Italy | | 1976 | | 1966 | | |
| Luxembourg | 1982 | 1961 | 1980 | 1976 | | 1976[i] |
| Netherlands | 1952 | 1969 | 1976 | 1970 | | 1963[h] |
| | 1979 | 1975 | 1977 | | | 1979 |
| | | | | | | 1983[i] |
| Norway | 1981 | | | | | 1977[b] |
| Portugal | 1976 | 1977 | | 1980 | | 1976[d] |
| | | | | | | 1983[b] |
| | 1983 | | | | | 1983[k] |
| Spain | | | 1975 | 1972 | | |
| Sweden | 1969 | 1969 | 1975 | 1969 | 1969[l] | 1964[d] |
| | 1981 | 1981 | | 1981 | 1981 | 1973[b] |
| | | 1983 | | | | |
| Switzerland | 1983 | 1971 | | | | 1966[d] |
| | | | | | | 1969[b] |
| | | | | | | 1979[d] |
| Turkey | 1983 | 1960 | | | | 1983[d] |
| | | 1971 | | | | |
| United Kingdom | 1974 | 1961 | 1974 | 1956 | | 1974[j] |
| | | 1974 | | 1968 | | 1975[c] |
| | | | | 1974 | | 1981[d] |

**Notes:**
a. Some federal countries such as Australia and Austria have laws at the state level.
b. Law on the general control of chemicals.
c. Law on compensation.
d. Law on nature conservancy.
e. Law on public health.
f. Law on protection of forests and forest areas.
g. Law on noise and air pollution from motor vehicles.
h. Law on nuclear energy.
i. Law on soil.
j. Law on noise.
k. Law on territory planning.
l. Essentially a specific administrative procedure.
**Source:** Organization for Economic Co-operation and Development, Reference 41, p. 242.

European matter. Indeed there was a tendency to believe that talk of the environment was part of a conspiracy to prevent modern development on our continent! Now we have reached the stage of recognizing that environmental concern and development have to be linked together if the latter is to be real and permanent. The question is how to do this" (44).

As acceptance of the validity of environmental concerns slowly spread, a recognizable theme of the many statutes passed during the decade was the centralization of authority at the national level. But of course, there are exceptions, even within individual countries. In India, for example, the 1981 air pollution control act covers all states, but the water pollution law is applicable only to those states that adopt it.

As to content, most developing countries are by and large still in the "react and cure" phase, while the developed nations are beginning to address a new agenda of "anticipate and prevent," though the earlier agenda is far from complete. In numerous developing countries, effective "react and cure" remains a distant goal, even where the desire to correct a problem is present. Air pollution in urban areas, for example, is chronic. Emissions legislation is typically inadequate, and those laws that do exist are poorly enforced. Many factories do not have pollution control equipment, even if such equipment has been mandated. Because of a lack of zoning policies, pollution-intensive industry has frequently been situated near or within residential areas, reinforcing the impact of industrial air pollution. Moreover, power plants and factories often burn high-sulfur coal and heavy residual oil, releasing large quantities of sulfur oxides and particulates into the urban atmosphere (45).

As for the developed countries, the issues cited in the Final Communiqué of the 1985 Bonn Economic Summit (attended by the United States, United Kingdom, France, the Federal Republic of Germany, Japan, Canada, and Italy) provide as good a snapshot as any of the concerns now occupying center stage:

> New approaches to strengthening international co-operation are essential to anticipate and prevent damage to the environment, which knows no national frontiers. We shall co-operate in order to solve pressing environmental problems such as acid deposition and air pollution from motor vehicles and all other significant sources. We shall also address other concerns such as climatic change, the protection of the ozone layer and the management of toxic chemicals and hazardous wastes. The protection of soils, fresh water and the sea, in particular of regional seas, must be strengthened (46).

The themes here are evident: a respectful bow toward "anticipate and prevent" policies; a concern with transboundary problems, especially those of acid deposition and associated forms of air pollution (see Chapter 12, "Multiple Pollutants and Forest Decline"); and an emerging recognition of fully global issues such as climate change. Finally, there is mention, as there might not have been a decade earlier, of the need for basic resource conservation; in this case, of soils. And the unmet cleanup needs of the "react and cure" agenda are still a high priority.

The newly prominent problems of transboundary pollution control are forcing sacrifices and adjustments that previous international agreements generally did not. In the past, international environmental controls have advanced at a rate largely determined by national self-interest and a will to harmonize domestic progress between neighbors.

But now there are signs that a true weighing of national with international interest is beginning. Examples can be found in the European Economic Community (EEC), bilaterally in North America, and in the Economic Commission for Europe (ECE). Until 1983, the EEC generally made proposals to its member states. But now Britain, the Federal Republic of Germany, France, and others are themselves making substantive proposals for multilateral consideration on air and water pollution as well as transfrontier shipments of waste (47). The 1983 German initiative on acid rain is the best example, for it forces a clear linkage between domestic and international policies and squarely inserts environmental issues on the diplomatic agenda. What must follow is an apportionment of the substantial costs involved in air pollution control among countries. In effect, Italy has to pay for damage to German forests, the United Kingdom for damage to Scandinavian forests, and so on. If this linkage is achieved, the European Community will have moved forward from a position of harmonizing national environmental regulations designed for the benefit of each member state's economy to one in which the wider European economy (and that of countries outside the EEC) is to the fore. It will be a slow and difficult process.

The Bonn Communiqué also called for greater integration of resource management and environmental policies with other policies. On pollution control, countries such as the Netherlands, Sweden, and the United States are trying to correct the inefficiencies of dealing with individual problems in separate programs. "This approach," says the OECD, "may only result in moving a pollutant from one medium (such as air) to another (water and land). The problem is not eliminated but just moved from one place to another, and in some cases may create a greater risk in the new location than in the old" (48). The Netherlands has a new statute requiring coordinated licensing procedures and plans to "integrate all the environmental laws with land use planning at the provincial level." Japan, the Federal Republic of Germany, and the Netherlands all have programs to address "soil pollution," which deal with pollutants regardless of source—from the air, in the water, or through waste disposal.

Attempts to integrate environmental protection with other governmental programs are not confined to pollution control. In France, Sweden, and the Federal Republic of Germany, industrial inspections and audits may now combine environmental protection with occupational health and safety. In the United States, the agencies responsible for pollution control, food and drug safety, occupational health, and consumer protection have attempted to coordinate many of the health protection provisions of their individual mandates. In resource conservation, there is a growing employment of complex "multiple-use" policies that recognize the many functions a single piece of land may serve, such as commercial timber production, wildlife habitat, soil conservation, hydrologic regulation, and recreation (49).

Finally, the Bonn Communiqué reflected the current political context when it talked of harnessing both the mechanisms of governmental vigilance and the disciplines of the market to solve environmental problems. The utility of the "polluter pays" principle was highlighted. Background material, based on the conclusions of the OECD Environment and Economics Conference of 1984, stressed that environmental regulation need not have a negative impact on macroeconomic performance. Analyses presented at the 1984 meeting demonstrated that net macroeconomic effects of environmental controls are very small for those economies studied (Finland, France, the Netherlands, Norway, and the United States) (50). The papers for that conference show how far economic evaluation of environmental policies in the OECD countries has come. The arguments for and against different modes of control, the costs of different standards, and the array of economic instruments available are laid out, and the impacts in terms of employment, productivity, inflation, and trade analyzed (51).

## International Agreements

Environmental problems have been handled at the local level for almost as long as human society has existed. By contrast, international attention is relatively recent, and attempts to achieve it in a systematic way have hardly reached beyond the stage of infancy (52).

The UNEP "Register of International Treaties and Other Agreements in the Field of the Environment" lists a total of 108 texts, including only two items approved earlier than 1939 (53). A more comprehensive register lists 257 relevant multilateral treaties for the protection of the environment that were signed before 1978. Of these treaties only 10 were signed before the end of 1939 (54).

The growth in the number of environmental treaties since the mid-1950s can be seen in Table 11.3. Table 11.4 shows a selection, drawn up by OECD, of the most recent and important conventions, showing the dates of signature and of entry into force upon ratification.

The most recent international agreement, the Global Convention on the Protection of the Ozone Layer, was signed March 22, 1985, by 20 countries and the EEC. For the first time in such an agreement, the Convention aims at *anticipating* a problem by calling for cooperation in research and monitoring, information exchange, and,

**Table 11.3 International Agreements on the Environment, 1968–1983**

| Year | Number of Agreements |
|---|---|
| 1868–99 | 2 |
| 1900–10 | 1 |
| 1911–19 | 0 |
| 1920–29 | 4 |
| 1930–39 | 3 |
| 1940–44 | 6 |
| 1945–49 | 27 |
| 1950–54 | 17 |
| 1955–59 | 38 |
| 1960–64 | 48 |
| 1965–69 | 44 |
| 1970–74 | 49 |
| 1975–79 | 39 |
| 1980–83 | 20 |

**Source:** Haigh, 1985, Reference 52.

**Table 11.4 International Legal Instruments Concerning the Environment[a]**

| No. | Purpose of Regulation | Type of Regulation[b] | Place and date | Entry into force |
|---|---|---|---|---|
| **Sea pollution** | | | | |
| 1. | Limitation of liability of owners of sea-going ships | Conv. | Brussels, 1957 | 5/31/68 |
| 2. | Prevention of marine pollution by ships and aircraft | Conv. | Oslo, 1972 | 4/7/74 |
| 3. | Prevention of marine pollution by dumping of wastes | Conv. | London, Mexico, 1972 | 8/30/75 |
| 4. | Prevention of pollution from ships (MARPOL) | Conv. | London, 1973 | 10/2/83 |
| 5. | Protocol to No. 4 (segregated ballast) | Prot. | London, 1978 | 10/2/83 |
| 6. | Marine environment of the Baltic Sea | Conv. | Helsinki, 1974 | 5/3/80 |
| 7. | Prevention of marine pollution from land-based sources | Conv. | Paris, 1974 | 5/6/78 |
| 8. | Protection of Mediterranean Sea | Conv. | Barcelona, 1976 | 2/12/78 |
| 9. | Protocol to No. 8 (dumping from ships and aircraft) | Prot. | Barcelona, 1976 | 2/12/78 |
| 10. | Protocol to No. 8 (protection against land-based sources) | Prot. | Athens, 1980 | 5/17/80 |
| 11. | Protocol to No. 8 (pollution by oil; cooperation in emergency cases) | Prot. | Barcelona, 1976 | 2/12/78 |
| 12. | Limitation of liability for maritime claims | Conv. | London, 1976 | Pending |
| 13. | Prevention of pollution of the sea by oil[d] | Conv. | London, 1954[c] | 7/26/58 |
| 14. | Pollution of the North Sea by oil[e] | Agr. | Bonn, 1969 | 8/9/69 |
| 15. | Civil liability for oil pollution damage | Conv. | Brussels, 1969 | 6/19/75 |
| 16. | Intervention on the High Seas | Conv. | Brussels, 1969 | 5/6/75 |
| 17. | Protocol to No. 16 (substances other than oil) | Prot. | London, 1973 | Pending |
| 18. | Protocol to No. 16 (CLC) | Prot. | London, 1976 | 4/8/81 |
| 19. | Cooperation against pollution of the sea | Agr. | Copenhagen, 1971 | 10/16/71 |
| 20. | International fund for compensation (oil pollution damage)[f] | Conv. | Brussels, 1971 | 10/16/78 |
| 21. | Civil liability for oil pollution damage-exploration of seabed mineral resources | Conv. | London, 1977 | Pending |
| 22. | Law of the Sea | Conv. | Montego Bay, New York, 1982 | Pending |
| 23. | Protection and development of the Wider Caribbean region | Conv. | Cartagena, Colombia, 1983 | Pending |
| **Nuclear** | | | | |
| 24. | Third party liability for nuclear energy | Conv. | Paris, 1960 | 4/1/68 |

**Notes:**
a. Signed or ratified by at least four OECD countries.
b. Agr. = Agreement, Conv. = Convention, Prot. = Protocol.
c. Renounced by several countries in 1983 and 1984.
d. Four amendments (London).
e. One amendment (Bonn, 1983).
f. FUND protocol, 1984.
g. Two supplements (Bonn, 1976).
h. One supplement.

**Source:** Organization for Economic Co-operation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris 1985), pp. 275-77.

eventually, for a protocol to control emissions of chloroflurocarbons, now considered by scientists to pose the greatest threat to the ozone layer and also contribute to the greenhouse effect. (See Chapter 10, "Atmosphere and Climate," Recent Developments.)

International law has developed rapidly as the planet has shrunk, since it is the only assured way of making nation states act in concert to overcome problems. Information exchange, conference pronouncements, and setting a good example are all parts of the process, but they cannot substitute for a body of law.

Yet the effectiveness of these international instruments varies widely. As conventions and treaties have had to deal with increasingly complex problems, their contents have become less precise and their effectiveness less predictable. Moreover, enforcement usually depends on the degree of general convergence of interests among the contracting parties. The more heterogeneous the contracting parties, the less precise and constraining the contents, and the less likely it is that they will be effectively enforced (55).

A good example of this phenomenon is the Convention on Long Range Transboundary Air Pollution prepared by the ECE, signed in 1979. The text is modeled on a prior convention signed by the members of the Nordic Council. In a comparison of the two conventions, it is striking how the greater number and variety of contracting parties have led to a significant reduction in the precision of

| No. Purpose of Regulation | Type of Regulation[b] | Place and date | Entry into force |
|---|---|---|---|
| 25. Protocol to No. 24 | Prot. | Paris, 1964 | 4/1/68 |
| 26. Supplementary to No. 24 | Conv. | Brussels, 1963 | 12/4/74 |
| 27. Liability of operators of nuclear ships | Conv. | Brussels, 1962 | |
| 28. Banning nuclear weapon tests in the atmosphere, outer space, and under water | Treaty | Moscow, 1963 | 10/10/63 |
| 29. Prohibition of nuclear weapons on the seabed, oceanfloor and sub-soil | Treaty | London, Moscow, Washington, 1971 | 5/18/72 |
| 30. Civil liability on maritime carriage of nuclear material | Conv. | Brussels, 1971 | 7/15/75 |
| **Fauna and flora** | | | |
| 31. Preservation of fauna and flora | Conv. | London, 1933 | 11/8/33 |
| 32. Establishment of the European Mediterranean Plant Prot. Org. | Conv. | Paris, 1951 | 4/18/51 |
| 33. Conservation of the living resources of the SE Atlantic | Conv. | Rome, 1969 | 10/24/71 |
| 34. Wetlands; waterfowl habitat | Conv. | Ramsar, Iran, 1971 | 2/2/71 |
| 35. Protection of world cultural and natural heritage | Conv. | Paris, 1972 | 11/23/72 |
| 36. Antarctic seals | Conv. | London, 1972 | 11/23/72 |
| 37. Polar bears | Agr. | Olso, 1973 | 5/26/76 |
| 38. Fishing and conservation of the Baltic Sea | Conv. | Gdansk, 1973 | 7/28/74 |
| 39. International trade in endangered species | Conv. | Washington, 1973 | 7/1/75 |
| 40. European wildlife | Conv. | Berne, 1979 | 6/1/82 |
| 41. Migratory species | Conv. | Bonn, 1979 | Pending |
| 42. Antarctic marine living resources | Conv. | Canberra, 1980 | 4/7/82 |
| **Rhine pollution** | | | |
| 43. Protection of the Rhine against pollution[g] | Agr. | Bonn, 1963 | 5/1/65 |
| 44. Rhine choride pollution[h] | Conv. | Bonn, 1976 | Pending |
| 45. Restriction of use of detergents | Agr. | Strasbourg, 1968 | 2/16/71 |
| **Miscellaneous** | | | |
| 46. Damage caused by space objects | Conv. | London, Moscow, Washington, 1972 | 8/17/72 |
| 47. Nordic environmental protection | Conv. | Stockholm, 1974 | 10/5/76 |
| 48. Prohibition of military environmental modification techniques | Conv. | New York, 1977 | 10/5/76 |
| 49. Long range air pollution | Conv. | Geneva, 1979 | 3/16/83 |
| 50. Transfrontier co-operation | Conv. | Madrid, 1980 | 12/22/81 |

the final text, although perhaps it is too soon to say whether the larger number of parties to the ECE convention—all of which must be involved if the convention is to achieve its objectives—can ultimately work together (56).

A major difficulty in making international law is the gap between what is agreed to in negotiation and what is subsequently acceptable to national parliaments. The best known recent example in the environmental field was the initial failure of the convention for reducing chloride pollution of the Rhine, signed in 1976. The text was so specific in its terms and so constraining on the signatories that the French National Assembly refused to agree to its ratification (57).

The road between a sound negotiated text and effective action is long and tortuous. Most conventions specify the number of ratifications that are required before a convention enters into force, and even when in force it is only effective in those states that have ratified. Ratification is a national matter; other countries cannot compel a state to ratify. The states that have both signed and ratified must then take the necessary legal and administrative steps to ensure that the ends specified in the convention are achieved.

Some measures in international law create new organizations, a process that is sometimes only the beginning of a whole new set of difficulties. (See Box 11.2.) Given the lack of policing and verification of international agreements, the difficulty of incorporating the texts into national laws, and the freedom of governments to interpret provisions as they see fit, it is easy to see why new environmental law is not always synonymous with progress. Sometimes, because of the apparent advance, the reverse is even true: "Out of sight, into law and out of mind."

## THE LARGER CONTEXT

Many actors other than those directly responsible for resource and environmental management have a great deal to do with the success or failure of the work of those directly involved. Public support and participation at the local level are crucial; so, ultimately, is a willing attitude in the business sector that recognizes its self-interest in sound environmental management. On the other hand, for many developing countries, the bilateral and multilateral assistance agencies can make a major difference. Bad policies—in terms of sustainable development—can send billions of dollars into counterproductive programs.

Here we briefly review the activities of some of those groups whose attitudes and actions strongly affect environmental outcomes. Subsequent editions of *World Resources* will review other diverse factors that determine the larger context, including: science and engineering, from basic research to new technologies; management of the international debt crisis; trade and protectionism; and the role of women.

### Citizen Efforts and Public Support

Within the OECD nations, public support for environmental improvement—even at the expense of economic growth—remains surprisingly strong. (See Fig. 11.1.) Only about one quarter of the people are willing to see the environment suffer in order to secure economic growth; in Japan, even fewer. Where public opinion polls have asked the same questions over many years, the majority favoring stronger programs has grown steadily, despite ever-tightening budgets or, as in the United States, hostile administrations.

The recent rapid growth in citizens' groups dedicated to the environment and related issues should therefore be no surprise, though its dimensions are striking. The history of citizen concern with the environment goes back to the last century and many of the NGOs now involved are well over 50 years old. But since the late 1960s the number has exploded. More than 3,000 NGOs are now listed with the Environment Liaison Center (ELC) in Nairobi, a clearinghouse for environmental NGO activity.

The major feature of the citizen-based organizations for the environment is their remarkable diversity. Organizations reflect the global range of political and religious opinion, the salient local issues, and countless modes of working. It is hopeless to generalize, although several valuable national and regional surveys exist (58,59).

The sheer volume of reports, lawsuits, field projects, research, rallies, and press notices generated by NGOs has tended to overwhelm the bureaucrat. Indeed, there is plenty of anecdotal evidence to suggest that administrators have a deepseated dislike of the tangle of NGOs, despite the fact that in many ways it is the NGOs who make the government worker's life possible in political terms.

Most NGOs are local and focused on the immediate problems of day-to-day survival, the quality of the local environment, and community needs. Their activities are crucial: from tree planting, family planning work, wildlife and habitat conservation, to monitoring and forcing the clean-up of pollution sources and hazardous waste dumps. And the world over, they protest against the status quo. Countless organizations are not only questioning how we should live with respect to natural resource constraints, but are the mainspring of change.

A series of publications capturing some of this diversity in the Third World was the product of a major gathering of "grass roots NGOs" held in New Delhi in February, 1984 (60). The overriding message of the 1,000-plus local projects reviewed in the process was that, at the community level, environment and development concerns are so closely linked that it is somewhat academic to separate them. Survival for the rural and urban poor is so dependent upon their immediate environs that its custodianship is a prerequisite to breaking out of the cycle of poverty.

This linkage of environment, development and, to a lesser extent, population groups, which grows out of community-based development in the Third World, is also beginning to characterize groups in the developed countries. In effect, the traditional environmental lobby that grew out of the conservationist tradition is adopting a wider focus. The trend is not without some pain as the leaders of the conservation movement struggle to keep

**Box 11.2 The International Tropical Timber Agreement**

In early 1985, the International Tropical Timber Agreement (ITTA) came into force after a decade of negotiation between timber consumers and producers, and a major international campaign to secure ratifications. It is primarily a trade agreement promoted by the United Nations Commission for Trade and Development (UNCTAD), but unlike other such agreements it envisages the sustainable development and environmentally sound management of the commodity it seeks to regulate. Such management is vital if the tropical forests are to survive. (See Chapter 5, "Forests and Rangelands.")

What has happened since is all too typical of the international system and illustrates the real difficulties of forging cooperative policies from divergent economic interests, even when agreement exists on paper.

The new timber organization met once in July and again in November 1985 in Geneva. Each time delegates hoped that the basic organizational questions of headquarters' location and choice of executive director could be settled, so that the business of forest management could begin. But, on each occasion, the unwieldy politics typical of international commodity agreements got in the way.

Japan, importer of 40 percent of all traded tropical timber, insisted that the headquarters be in Yokohama. The North American and European group of importers preferred Amsterdam. Asian timber exporters, chief among them Malaysia and Indonesia, wanted Jakarta, and Latin American producers favored Rio de Janeiro.

Each location had its supporters from among the 37 ITTA members, but none managed to gain a simple majority of the distributed votes. Votes are allocated by means of a complex formula, with producers dividing 1,000 votes according to the export value of their timber trade, and the area of forest they possess. Thus Latin America, which has only 7 percent of the tropical timber trade, receives additional votes because it has 70 percent of the world's tropical forests.

Each consumer nation gets 10 votes when it joins, plus additional votes calculated according to the volume of its timber imports. Japan, with 398, has more votes than any other single consumer nation, and needs the support of only a few other countries to swing the balloting its way. Instrumental in the process of creating the timber agreement, the Japanese want to play a major role in the organization. But the other producer and consumer blocks appear equally committed to ensuring that their interests are well served within the ITTA. At its most recent meeting, the council resorted to secret balloting, a procedure that UNCTAD, in its caretaker role in many sensitive trade negotiations, has not found necessary since 1972. Even when Latin American producer nations withdrew Rio de Janeiro as a proposed headquarters site, the deadlock could not be resolved.

Though interest in the timber agreement and in the problems of deforestation still runs high, time is running out for ITTA. To date, its administrative expenses have been met by a $270,000 special advance from the U.N. General Assembly. This money has been used to hold the Geneva meetings, but is only a loan. ITTA members will have to come up with funds to pay back the loan, and to finance their next meeting.

an eye on their past concerns. But environment, as far as the citizen NGOs are concerned, has moved a long way from pandas and pollution control.

Similarly, "development" NGOs are increasingly recognizing the environmental component in their work and are beginning to promote an environmental message in their fundraising and opinion-forming activities. For example, the Swedish Red Cross and Earthscan recently published *Natural Disasters: Acts of God or Acts of Man?* investigating the degree to which environmental destruction from man's activities is the real cause of major floods, famines, and other "natural" disasters (61). The 1985 Global Meeting on Environment and Development, described earlier, included a broad range of development groups such as OXFAM, and the International Coalition for Development Action (ICDA) as well as the traditional environmental groups.

At the national level the thrust of environmental organizations is becoming more political. But how this manifests itself in terms of political parties varies, depending in part upon the voting system that applies. Thus in the Federal Republic of Germany, Holland, and Belgium, where there is a system of proportional representation, "green" parties have political force. To varying degrees, the major political parties in many countries, including Canada, New Zealand, the United Kingdom, and the United States are influenced by the environmental movement's ever-expanding agenda. This influence extends from the village green to the reform of the European Common Agriculture Agenda, from wood stoves to nuclear power, and from aid projects to international debt.

## Business and Industry

The first decade of the environmental movement was marked in some places by confrontation between business and NGOs on almost every issue. While this posture persists, it is slowly giving way to a recognition on both sides that cooperation can accomplish more, with less delay for business activities, and at less cost (62). The new relationship comes from greater familiarity with the issues on the part of the business sector and the experience of a growing number of firms that good environmental practice is not prohibitively expensive, indeed that it may occasionally even improve the bottom line. On environmentalists' part, there is a new maturity and a recognition of business' immense influence—because of the size of investment and lending—on the futures of the developing countries. (See Table 11.5.)

Business' position, at least at the rhetorical level, was set out at WICEM. But who is bridging the gap between industrial activity and environmental needs? There are a few bridging institutions such as the UNEP Industry Office in Paris and the International Environmental and Development Service (IEDS), established in 1983 by the World Environmental Center (WEC). On the recipient government's request, IEDS supplies pollution-control experts from industry free of charge to provide technical advice. Industry volunteers specialists; U.S. AID pays their expenses. It is an innovative and effective program, but small compared to the need.

Another bridging initiative, UNEP's report on WICEM noted, was the 1984 international conference on the role of multinational corporations in developing countries, attended by corporate and industry association executives, developing country environmental officials, and other experts. This diverse group's conclusions appeared in 1985 as *Guidelines for Growth*, a set of commendable recommendations for host governments and corporations alike. Unfortunately, some of these recommendations, while perfectly reasonable, are out of reach of some developing country governments. For example, the report

**Table 11.5 Total Net Receipts of Developing Countries From All Sources, 1970–83**
*(billions of constant 1982 US dollars)*

| | 1970 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Official Development Assistance (ODA):** | **21.10** | **30.23** | **28.97** | **27.59** | **31.70** | **32.68** | **35.34** | **36.48** | **34.74** | **33.82** |
| Bilateral | 18.30 | 24.44 | 23.36 | 21.16 | 24.83 | 26.24 | 28.00 | 28.72 | 27.23 | 26.25 |
| Multilateral agencies | 2.79 | 5.78 | 5.61 | 6.43 | 6.88 | 6.44 | 7.34 | 7.76 | 7.51 | 7.54 |
| **Grants by private voluntary agencies** | **2.24** | **2.02** | **1.96** | **1.98** | **1.89** | **2.01** | **2.28** | **1.98** | **2.31** | **2.21** |
| **Non-concessional flows** | **28.59** | **51.67** | **54.85** | **58.89** | **65.39** | **53.83** | **55.93** | **68.94** | **60.36** | **63.23** |
| Official or officially supported: | 10.34 | 15.86 | 19.30 | 20.92 | 21.49 | 18.98 | 23.02 | 21.67 | 21.99 | 19.70 |
| Private export credits (DAC)[a] | 5.46 | 6.66 | 9.77 | 11.77 | 11.10 | 9.13 | 10.48 | 11.06 | 7.09 | 5.53 |
| Official export credits (DAC) | 1.54 | 1.81 | 2.01 | 1.92 | 2.54 | 1.79 | 2.32 | 1.97 | 2.66 | 2.11 |
| Multilateral | 1.85 | 3.81 | 3.68 | 3.58 | 3.53 | 4.29 | 4.57 | 5.59 | 6.61 | 7.03 |
| Other official and private flows (DAC) | 0.65 | 1.13 | 1.16 | 0.84 | 1.56 | 1.18 | 2.11 | 1.92 | 2.63 | (3.02) |
| Other donors[b] | 0.84 | 2.45 | 2.68 | 2.81 | 2.76 | 2.59 | 3.53 | 1.13 | 3.00 | (2.01) |
| Private: | 18.25 | 35.81 | 35.55 | 37.98 | 43.90 | 34.85 | 32.91 | 47.28 | 38.37 | 44.52 |
| Direct investment | 9.63 | 17.11 | 12.04 | 13.08 | 13.26 | 13.85 | 9.93 | 16.87 | 11.86 | 7.84 |
| Bank sector[c] | 7.83 | 18.07 | 21.74 | 20.64 | 26.17 | 20.30 | 21.68 | 29.35 | 26.00 | 36.18[d] |
| Bond lending | 0.78 | 0.63 | 1.77 | 4.26 | 4.47 | 0.70 | 1.30 | 1.06 | 0.51 | 0.50 |
| **Total receipts** | **51.93** | **83.92** | **85.78** | **88.47** | **98.98** | **88.52** | **93.45** | **107.40** | **97.41** | **100.25** |
| Sources of ODA to Developing Countries and Multilateral Agencies *(percent)* | | | | | | | | | | |
| DAC countries | 83 | 63 | 62 | 66 | 66 | 69 | 69 | 68 | 75 | 76 |
| OPEC countries | 5 | 28 | 29 | 25 | 26 | 23 | 24 | 23 | 16 | 15 |
| CMEA[e] and other countries | 12 | 9 | 9 | 9 | 8 | 8 | 7 | 9 | 9 | 9 |
| **Total** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |

**Notes:**
a. Development Assistance Committee of OECD.
b. Other official flows from OPEC countries, Luxembourg (up to and including 1981), Spain, and Yugoslavia.
c. Excluding (i) bond lending and (ii) export credits extended by banks which are included under private export credits. Including loans by branches of OECD banks located in offshore centers, and for 1980, 1981, and 1982 participation of non-OECD banks in international syndicates.
d. The sharp rise in 1983 reflects debt-rescheduling arrangements, not a real increase in financing.
e. Council for Mutual Economic Assistance (CMEA).
**Source:** Organization for Economic Co-operation and Development (OECD), *Development Co-operation, 1984 Review* (OECD, Paris, 1984), p. 65.

notes that "delays, uncertainty, and unpredictable changes in environmental regulations do discourage investors, and should be avoided" (63). While unarguable, the recommendation is nonetheless irrelevant to a country with little or no environmental policy or one that undergoes regular political coups.

As it is for so many government administrators, the lack of reliable information is a real constraint to progress in the private sector. A 1984 U.S. Council on Environmental Quality survey of 45 large U.S. corporations concluded that corporations urgently need more international data and believe that the government's natural resource forecasts are not credible. Government's data, say business experts, are not up to date, although they are, nonetheless, business' principal source of information (64). Nearly all of those surveyed (96 percent) favored the creation of an international clearinghouse for natural resource information and improvement in the credibility of government natural resource forecasts.

## United Nations Environment Program (UNEP)

Since its creation following the 1972 Stockholm conference, UNEP has been the international agency charged with spreading sound environmental policies inside and beyond the U.N. system. Over the years, as more and more countries have taken on environmental issues as a priority, they have turned to UNEP for technical advice, support and coordination.

But this tiny "catalytic" agency is not in a position to respond fully. With a small and politically vulnerable annual budget of $30 million, and the power to convince but not to coerce, UNEP is a David confronting a Goliath of issues. While it has been called "the environmental conscience of the U.N. system" and the source of many important initiatives, contributions to UNEP's budget are voluntary, unlike the official U.N. "specialized agencies" such as the World Health Organization. It is charged only with coordinating the environmental activities of other U.N. agencies and international organizations, and encouraging national programs. And with a staff of about 160, it is dwarfed by the vast U.N. system. Though symbolically important, UNEP's location in Nairobi has not improved its accessibility or efficiency.

UNEP's answer to its mandate to coordinate the environmental activities of the rest of the United Nations is a device known as the "system-wide medium-term environmental plan" (SWMTEP). As the name hints, it is a slow and cumbersome means of producing consensus. At UNEP's Governing Council meetings, now held every two years, many nations, large and small, show unwillingness to commit secure levels of funding, while demanding an elaborate program of work. About one third of UNEP's operating budget has come from the United States, where it is the subject of an annual political struggle.

With its limited budget, UNEP depends on a small professional staff to understand, coordinate, and report on the sea of environment related activities throughout the international system. Staff turn-over has been high in many important areas (65). The program cannot criticize or praise member countries for their environmental actions, making it difficult to focus public attention on the best and the worst situations and policies.

In many ways it is a hopeless task. Nevertheless, UNEP has some solid achievements to its credit. It has helped catalyze a number of important initiatives, many of them described in this volume, including the World Conservation Strategy, the Regional Seas Program, WICEM, and environmental work by the multilateral development agencies and banks. It has raised public awareness by inserting the environmental dimension in dozens of other U.N. programs. Perhaps most significant has been its contribution in the fields of environmental data collection and assessment through GEMS, GRID, and other efforts.

### International Assistance—Multilateral Flows

The World Bank is the largest single source of external development assistance for many poor countries. Because of its size and its large professional staff—more than 3,000—it is also often the policy leader in development assistance. In 1978 the World Bank's environmental practices received a qualified endorsement in a study of international development agencies called *Banking on the Biosphere?* by the International Institute for Environment and Development (IIED) (66). A year later, the Bank's environmental office, together with UNEP, was instrumental in formulating the Declaration of Environmental Policy and Procedures and in forming the Committee of International Development Institutions on the Environment (CIDIE). CIDIE has had a series of lack-luster meetings every year since, involving a dozen or so of the multilateral development agencies and regional development banks (67).

Yet in recent years the Bank has been the target of widespread, international pressure to become more ecologically sophisticated and responsible. It has been urged to expand its Office of Environmental and Scientific Affairs because that office has only a small voice in decisions on which projects are to be financed. The office is also understaffed and underfunded to review the hundreds of projects amounting to $14 billion that the Bank funds annually in 80 different countries. Because of the sheer size of World Bank projects, which average about $10 million, the Bank's activities are inherently more likely to have environmental side-effects than those of small agencies.

For example, World Bank ecologist Robert Goodland characterizes much of the criticism directed at Bank-funded water projects: These large capital-intensive projects, which have been a major focus of Bank lending, destroy natural environments and rob inhabitants of the resources their watersheds provide. Goodland noted that major water projects can cause "massive damage" such as the "failure of involuntary human resettlement, irreversible loss of wildlife and genetic diversity, loss of agricultural and forest land by inundation, reduction of site-related soil fertility, intensified erosion below the dam, sedimentation into the reservoir, induced seismicity, and an increase in water-related diseases such as malaria and schistosomiasis" (68).

In 1984 the Bank set out its environmental policies, procedures and requirements (69,70). These documents attach great importance to environmental questions within the project cycle and in the economic and sector work of the Bank. But there is an acute shortage of environmental specialists on the Bank's large staff (71), and environmental considerations are not routinely considered early and thoroughly enough in the design of individual projects (72). In testimony before a U.S. Senate subcommittee, the U.S. Treasury pointed to another problem. It suggested that all the multilateral banks tend to overemphasize the quantity rather than the quality of lending: "We suspect that the problems encountered in the environmental aspects of projects may be an instance of such an overemphasis. If environmental considerations threaten expeditious project processing, the environment is assigned low priority and is left to be dealt with later" (73). In effect, under current procedures, the desire to accelerate development assistance is pitted against environmental and social considerations. The conflict is not inherent; improved procedures would resolve much of the problem. However, because of the vastness and diversity of the Bank's lending, it is no mean task to determine how to make these changes. Still, indications are that the Bank's lending is more rigorously scrutinized than that of the regional banks for Asia, Latin America, and Africa, and the Bank is currently attempting to identify ways to better integrate resource and environmental concerns into its programs.

While the capacity of the multilateral agencies to anticipate the environmental consequences of their project lending is still inadequate, lending for projects specifically designed to improve or rehabilitate the environment has increased. Also, the World Bank is a leader in the effort to slow tropical deforestation (74), and it has highlighted the need to pay greater attention to environmental and resource constraints in developing a new lending strategy for sub-Saharan Africa (75).

### Bilateral Assistance

Most bilateral aid agencies have expressed the right sentiments about the importance of environmental problems. However, many would go on to point out that they *respond* to requests for assistance and do not have the freedom to lay down the rules. They would also emphasize that the broader context of international development is more important than environmental concerns. Political instability, lack of human resources, corruption, and the international economic setting are the principal problems, and not the environmental or social procedures they follow. Yet there is room for progress.

A recent review by IIED of the environmental procedures and practices of the national aid agencies of Canada, the United States, the Federal Republic of Germany, the United Kingdom, the Netherlands, and Sweden, concluded that U.S. AID was the only agency with systematic, enforceable procedures backed by the staff necessary to carry them out (76). Since then, the Nordic, Dutch, and West German agencies have made some progress on the policy level, have begun to make some money available for environmental programs, and have produced guidelines or checklists to guide their programs (77,78,79).

However, developing the language is one thing; putting the ideas to use another. A subsequent study of the guidelines drafted and used by the major development agencies concluded that there was little evidence of the systematic application of the existing texts (80). (U.S. AID has gone beyond guidelines and adopted formal regulations. The study does not suggest that these regulations are not being followed.) Some agencies never put some environmental guidelines into operation because their purpose was only to improve public relations or to provide educational material to the development community in general. In other cases staff of agencies do not use guidelines systematically because they are too general or incompatible with real tasks and problems. In many cases the agencies do not organize the appropriate training, nor establish any institutional penalties for failing to use the guidelines.

Most of the major bilateral assistance agencies would probably accept the following environmental objectives:

- To ensure that environmental planning is not left out of development planning or the aid project cycle;
- To raise indigenous environmental/natural resource management capability to enable such planning to occur;
- To gather sufficient hard data of an environmental kind (taxonomic, ecological, geological, etc.) for the same ends;
- To encourage public education, particularly in the developing countries, since judgments and policies must increasingly be made at the country level;
- To concentrate financial and human resources on systems and sectors that are particularly at risk: be they deserts, watersheds, moist forests, the urban environment, renewable energy supply, or sustainable agriculture/forestry.

There would be argument over environmental techniques within the aid process, with some, for example, preferring formal impact assessments, others a looser review. Priorities would differ among countries. Guidelines would be employed (or not) as indicated above. In a few cases, a body of "law" would help ensure that environmental considerations are addressed, as in the case of U.S. AID and the European Development Fund. The Lome III convention among the African, Caribbean, and Pacific States, and the European Community and its member states contains general articles on environment as well as specific items on reforestation, desertification, and sustainable yield management (81). But, sadly, there is little evidence that the funding, staffing, or will is there to see these sound policies put into effect.

## CONCLUSION

A review such as this cannot definitively answer the question whether the world's institutions are responding adequately to the environmental needs before them. Solid answers would require far more country-by-country data than exist today, and a volume as large as the one before you. Yet this preliminary survey does permit some conclusions. Environmental policy is more sophisticated and is being practiced more widely than ever before. Few if any governments any longer see conservation of natural resources as irrelevant to their economic goals. Most have taken steps, at least on paper, to protect their environments, and public support of such policies is strong (though little is known about public opinion on this subject in many parts of the world). Nevertheless, many of the tools for sound management are weak. In a great many countries, even where there is a political commitment and adequate legislation, implementation, enforcement, and monitoring are generally deficient. The reasons are an intimidating combination of inadequate financial resources, trained staff, technical capabilities, and reliable data.

Though domestic issues still pose formidable challenges—from soil erosion to toxic waste disposal—the environmental policy agenda is becoming increasingly crowded with issues that must be addressed on a regional or even global basis. In the cases of acid deposition and associated forms of transboundary air pollution, and of changes in the ozone layer, governments are taking the first tentative steps to find ways to address them. Still, however, the record of accomplishment of the more straightforward, traditional international agreements is weak. Finally, the course of economic development in the Third World is strongly influenced by external funds—from official sources of assistance and direct investment by the private sector—and here there is room for much needed progress if sound environment and resource management policies are to be widely achieved.

## References and Notes

1. This issue is discussed in: J.G. Speth, "Protecting Our Environment: Toward a New Agenda," *Alternatives for the 1980s*, No. 18 (Center for National Policy, Washington, D.C., June 1985), pp. 16–17.
2. Organization for Economic Co-operation and Development (OECD), *Economic and Ecological Interdependence: A Report on Selected Environment and Resource Issues* (OECD, Paris, 1982).
3. H. Kessel, *Environmental Awareness in the Federal Republic of Germany, England and the United States* (International Institute for Environment and Society, Berlin, 1984); and L. Harris, speech to the Wildlife Institute, Washington, D.C., March 18, 1985.
4. United Nations, *Conference on the Human Environment* (United Nations, Stockholm, Sweden, 1972).
5. An overview of the evolution of the sustainable development concept is provided in: U.N. Center for Transnational Corporations, *Environmental Aspects of the Activities of Transnational Corporations: A Survey* (United Nations, New York, 1985), Chapter 1.
6. International Union for Conservation of Nature and Natural Resources (IUCN), *World Conservation Strategy* (IUCN, Gland, Switzerland, 1980), Section 1.
7. World Resources Institute (WRI), *Improving Environmental Cooperation: The Roles of Multinational Corporations and Developing Countries* (WRI, Washington, D.C., 1984), p. 35.
8. C. Pearson, *Down to Business: Multinational Corporations, the Environment and Development* (World Resources Institute, Washington, D.C., 1985), p. 13.
9. Inter-Parliamentary Union (IPU), *Conference Report on Environment, Nairobi* (IPU, Geneva, 1984).
10. *Ibid.*
11. World Resources Institute (WRI), *The Global Possible: Resources, Development, and the New Century* (WRI, Washington, D.C., 1984), Foreword.
12. *Ibid.*, p. 1.
13. *Ibid.*, Foreword.
14. G.H. Brundtland, *UNEP News* (January 1985), p. 12.
15. World Commission on Environment and Development (WCED), *Mandate for Change* (WCED, Geneva, 1985).

16. *Op. cit.* 6, Section 1.
17. International Union for Conservation of Nature and Natural Resources (IUCN), *National Conservation Strategies: A Framework for Sustainable Development* (IUCN, Conservation for Development Center, Gland, Switzerland, January 1984), p. 34.
18. International Union for Conservation of Nature and Natural Resources (IUCN), November 1985 (personal communication).
19. United Nations Environment Program (UNEP), "World Industry Conference on Environmental Management, Outcome and Reactions," in *Industry and Environment*, Special Issue No. 5 (UNEP, Nairobi, 1984), p. 1.
20. M. Strong, keynote address, in *Sustainable Development: Report of the Proceedings of the Global Meeting on Environment and Development* (Environment Liaison Center, Nairobi, 1985), pp. 83–89.
21. Environment Liaison Center, "Global Meeting Stresses Participation and NGO Action," *Ecoforum*, Vol. 10, No. 1 (February 1985), p. 1.
22. A. Agarwal, welcoming speech, *Sustainable Development: Report of the Proceedings of the Global Meeting on Environment and Development* (ELC, Nairobi, 1985), pp. 9–11.
23. P. Hulm, "The Regional Seas Program: What Fate for UNEP? Crown Jewels?," *AMBIO*, Vol. 12, No. 1, pp. 2–13 (1983).
24. M. Holgate, *et al.*, Eds., *The World Environment, 1972–1982* (United Nations Environment Program, Dublin, 1982), p. 622.
25. P. Thacher, "Space Technology and Resource Management," *Journal of International Affairs*, Vol. 39, pp. 151–166 (1985).
26. J. Fanshawe, *Global Resource Information Database* (United Nations Environment Program, England, 1985).
27. Center for Science and Environment (CSE), *The State of India's Environment 1982, A Citizen's Report* (CSE, New Delhi, 1982); and Center for Science and Environment, *The State of India's Environment 1984–85, The Second Citizen's Report* (CSE, New Delhi, 1985).
28. L. Brown, *et al.*, *State of the World* 1984, 1985, and 1986 (W.W. Norton and Co., New York, 1984, 1985, 1986).
29. J. Horberry, *Status and Application of Environmental Impact Assessment for Development* (International Union for Conservation of Nature and Natural Resources, Conservation for Development Center, Gland, Switzerland, 1984).
30. United Nations Environment Program (UNEP), *The Use of Environmental Impact Assessment of Development Projects* (UNEP, Bangkok, 1982).
31. G. Conway, *Rapid Rural Appraisal* (Imperial College Center for Environmental Technology, London, 1985).
32. J. Tosi, Jr., *Land Capability Survey and Land Use Planning* (Tropical Science Center, Costa Rica, 1985).
33. R.A. Carpenter and J.A. Dixon, "Ecology Meets Economics: A Guide to Sustainable Development," *Environment*, Vol. 27, No. 5, p. 6 (June 1985).
34. *Ibid.*, p. 11.
35. R. Repetto, *et al.*, "Natural Resource Accounting in a Resource Based Economy: An Indonesian Case Study," presented at World Bank/UNEP Environmental Accounting Workshop (World Resources Institute, Washington, D.C., 1985).
36. United Nations Environment Program (UNEP) and the World Bank, "Environmental Accounting: A Report with Scientific Recommendations," in *Environmental Accounting Workshop* (UNEP and the World Bank, Washington, D.C., November 1984), Executive Summary, p. 1.
37. Norwegian Long-Term Program (1986–89), Royal Norwegian Ministry of Finance, Norway, 1984.
38. World Environment Center, *The World Environment Handbook* (World Environment Center, New York, 1985), pp. VIII–X.
39. *Ibid.*
40. O. Sunkel, "Debt, Development and Environment," presented at World Commission on Environment and Development, 4th meeting, São Paulo, Brazil, October 1985, p. 7.
41. Organization for Economic Co-operation and Development (OECD), *The State of the Environment* (OECD, Paris, 1985), p. 241.
42. *Ibid.*
43. H.J. Leonard, Ed., *Divesting Nature's Capital* (Holmes and Meier Publishers, Inc., New York, 1985), p. 70.
44. Food and Agriculture Organization (FAO), "World Leaders Address the Hunger Issue," *Ceres*, Vol. 18, No. 5/S (FAO, Rome, October 16, 1985).
45. *Op. cit.* 43.
46. Bonn Economic Summit, *Final Communiqué* (Pressemitteilung, Bonn, 1985), IV, "Environmental Policies," p. 8.
47. N. Haigh, *EEC Environmental Policy and Britain* (Environmental Data Services, London, 1984).
48. *Op. cit.* 41, p. 247.
49. *Op. cit.* 41, p. 247.
50. Organization for Economic Co-operation and Development (OECD), *International Conference, June 18–21, 1984*, Sessions 1–3 (OECD, background papers, Paris, 1984).
51. *Ibid.*
52. N. Haigh, *Vienna Center Project ECO I. Collaborative Arrangements for Environmental Protection in Western Europe*, (Institute for European Environmental Policy, European Cultural Foundation, London, 1985), p. 4.
53. United Nations Environment Program (UNEP), *Register of International Treaties and Other Agreements in the Field of the Environment*, Rev. 1 (UNEP, Nairobi, 1985).
54. W. Burhene, Ed., *International Environmental Law: Multilateral Treaties* (Erich Schmidt Verlag, Berlin, 1985).
55. *Op. cit.* 52, p. 4.
56. *Op. cit.* 52, p. 4.
57. *Op. cit.* 52, p. 4.
58. For example: State University of Leiden, Centre for Environmental Studies, *Environmental NGOs in Developing Countries* (Director General for Environmental Protection of the Ministry of Housing, Physical Planning and Environment, The Hague, 1985).
59. For example: Sierra Club, *World Directory of Environmental Organizations* (Public Affairs Clearinghouse, Claremont, California, 1976).
60. The International Exposition of Rural Development (IERD), *The Overview. Sharing Approaches That Work* (IERD, Coordination Centre, Brussels, 1984).
61. L. Timberlake and A. Wijkman, *Natural Disasters/Acts of God or Acts of Man?* (Earthscan, London, 1984).
62. K. Gilbreath, Ed., *Business and Environment: Toward Common Ground*, 2nd Edition (Conservation Foundation, Washington, D.C., 1984).
63. World Resources Institute (WRI), *Guidelines for Growth: Multinational Corporations and Environment in Developing Countries* (WRI, conference statement and action agenda, Washington, D.C., 1984), p. 5.
64. R.E. Train, *Corporate Use of Information Regarding Natural Resources and Environmental Quality* (World Wildlife Fund, Washington, D.C., 1984), pp. ii and iii.
65. R. Clark and L. Timberlake, *Stockholm Plus Ten* (International Institute for Environment and Development/Earthscan, London, 1982).
66. R.E. Stein and B.D.G. Johnson, *Banking on the Biosphere?* (Lexington Books, Lexington, Massachusetts, 1979).
67. United Nations Environment Program (UNEP), *Annual Report of the Executive Director, 1984* (UNEP, Nairobi, 1985).
68. R. Goodland, "Environmental Effects of Large Dams," *Nature* (in press, 1986).
69. The World Bank, Office of Environmental and Scientific Affairs, *Environmental Policies and Procedures of the World Bank* (the World Bank, Washington, D.C., 1984).
70. The World Bank, Environment and Science Unit, *Requirements of the World Bank* (the World Bank, Washington, D.C., 1984).
71. U.S. House of Representatives, *Draft Recommendations on the Multilateral Banks and the Environment*, Hearings before the Subcommittee on International Development Institutions and Finance of the Committee on Banking, Finance, and Urban Affairs, Serial Number 98-113 (U.S. Government Printing Office, Washington, D.C., Sept. 11, 1984), pp. 5–6.
72. J.W. Conrow, U.S. Treasury Department, Statement before the Subcommittee on International Development Institutions and Finance of the House Committee on Banking, Finance and Urban Affairs, Serial Number 98-113 (U.S. Government Printing Office, Washington, D.C., Sept. 11, 1984), p. 17.
73. D.C. Mulford, "Environmental Considerations in Multilateral Development Bank Projects," Statement before the Subcommittee on Foreign Operations of the Senate Appropriations Committee, Serial Number 99-316 (U.S. Government Printing

Office, Washington, D.C., Sept. 18, 1985).
74. World Resources Institute (WRI), the World Bank, and U.N. Development Program, *Tropical Forests: A Call for Action*, Vols. I, II, III (WRI, Washington, D.C., 1985).
75. The World Bank, *Toward Sustained Development in Sub-Saharan Africa*, (the World Bank, Washington, D.C., 1984), pp. 24–25 and 32–33.
76. For the study of the multilateral agencies (the World Bank and the Interamerican Development Bank, the Asian Development Bank, the Caribbean Development Bank, the African Development Bank, and the Arab Bank for Economic Development of Africa): *op. cit.* 66; and for the studies of the bilateral agencies of Germany, the United Kingdom, the United States, Canada, Sweden, and the Netherlands: B.D.G. Johnson and R.O. Blake, *Environmental and Bilateral Aid* (International Institute for Environment and Development, London, 1980).
77. J.D. Runnalls, "Factors Influencing the Environmental Policies of Development Assistance Agencies," in *Asian Development Bank Symposium* (Manila, February 1986).
78. J.A.J. Horberry, *Development Assistance and the Environment, A Question of Accountability* (Massachusetts Institute of Technology, unpublished, Cambridge, Massachusetts, 1984), pp. 13–20.
79. Nordic Working Group for Environment and Development Assistance, *Miljö och Bistand* (Nordic Council, Stockholm, 1982).
80. J. Horberry, *Environmental Guidelines Survey: An Analysis of Environmental Procedures and Guidelines Governing Development Aid* (International Institute for Environment and Development and the International Union for Conservation of Nature and Natural Resources, London and Gland, 1983).
81. Environment Liaison Center, "Lome III: NGOs—The Ball Is in Your Court," *Ecoforum*, Vol. 10, No. 1 (February 1985).

# 12. Multiple Pollutants and Forest Decline

A specter is haunting Europe and North America—the specter of widespread forest decline. The mass mortality of trees observed across large areas of Central and Eastern Europe over the past five years seems to be accelerating. Europe's forests appear to be threatened by a mysterious and deadly combination of airborne pollutants and natural stresses, including climatic factors and pathogens. New evidence suggests that a similar process is undermining the health of North America's high elevation eastern coniferous forests. Despite the frenetic research programs launched over the past few years to discover the causes of *Waldsterben* (forest death)—the collective name given to this frightening collection of symptoms in West Germany—there is no scientific consensus as to its primary triggering agents. (See Table 12.1.) Sorting out the causal agents is among the most challenging scientific detective tasks of the century. Given the severity of the *Waldsterben* syndrome there is no time to lose in grappling with its causes and formulating effective control strategies.

The stakes are high. The future health and vigor of virtually every major species of conifer and broad-leafed tree in Europe are threatened, as well as some commercially important conifers in North America (1). Also at risk is the future of the multi-billion dollar forest industry, which provides jobs for 1.4 million people in the European Economic Community alone (700,000 in West Germany). The ultimate victims, however, may be forest ecosystems themselves, which may be gradually degraded and perhaps genetically impoverished by humankind's polluting activities.

The extent of destruction is staggering. Today, nearly 6 million hectares of forests have been affected by *Waldsterben* in just five countries: West Germany, Austria, Czechoslovakia, Poland and Yugoslavia (2). Extensive forest damage has also been reported in East Germany, Hungary, Rumania, the Netherlands, Belgium, France, Switzerland, Sweden, and the United States. It is said to be appearing in the Soviet Union (though to an unknown degree), as well as Great Britain, Spain, Italy, and Canada (3). (See Box 12.1.)

When the first signs of this unique disease phenomenon began to show up in the early 1970s on West German white fir (*Abies alba*, also called silver fir), forest researchers thought it might be similar to the white fir decline (*Tannensterben*) that had been periodically affecting fir forests in central Europe for the past 250 years (4). But, in the late 1970s the decline symptoms spread to Norway spruce (*Picea abies*) and by 1980 it was apparent that scientists were faced with an entirely new set of forest decline symptoms, some of which are unprecedented in the literature of forest diebacks and declines.

The fir and spruce forests were only the first to be affected. Scotch pine (*Pinus sylvestris*, called Scots pine in Europe) began to decline throughout its range in 1980, followed by European beech (*Fagus sylvatica*) (5). Now *Waldsterben* affects at least 11 species in Europe: four of the most important conifers including Norway spruce,

## Table 12.1 The Common Symptoms of *Waldsterben*

**Growth-Decreasing Symptoms:**

- Discoloration and loss of foliar biomass (yellowing and browning of needles and leaves)
- Loss of feeder-root biomass, especially in conifers
- Decreased annual increment (width of growth rings)
- Premature senescence (aging) of older needles in conifers
- Increased susceptibility to secondary root and foliar pathogens
- Death of herbaceous vegetation beneath affected trees (all within the drip line of the canopy)
- Prodigious production of lichens on affected trees
- Death of affected trees

**Abnormal-Growth Symptoms:**

- Active shedding of needles and leaves while still green, with no indication of disease
- Shedding of whole green shoots, especially in spruce
- Formation of stork's nest crowns in young white fir
- Altered branching habit and greater than normal production of adventicious (out-of-place) shoots
- Altered morphology of leaves
- Altered allocation of photosynthate
- Excessive seed and cone production year after year
- Diseased trees show growth at top, not near bottom, with very brittle branches

**Water-Stress Symptoms:**

- Altered water balance
- Increased incidence of wet wood disease

**Note:** Table 12.2 compares these symptoms in European and North American forest declines and suggests possible causative agents.
**Source:** Schütt and Cowling, 1985, Reference 1.

## Box 12.1. The Scorecard of European Destruction

Across the European continent and into southern Scandinavia the scourge of *Waldsterben* is spreading rapidly, like an uncontrolled cancer. At the end of 1985, forests had been stricken across at least 7 million hectares in 15 European countries (both East and West) (1).

### WESTERN EUROPE AND SCANDINAVIA

1. West Germany is the most seriously affected country in Europe with 52–55 percent of its forests, covering nearly 4 million hectares, in various stages of decline and death. *Waldsterben* has devastated the Federal Republic's forests with alarming speed. In 1982, only 8 percent of the country's forests (not individual trees) showed signs of damage. By 1983 this figure had jumped to 34 percent, and in 1984 the Federal Ministry of Food, Agriculture and Forestry, reported that 50 percent of the forests were suffering. The 1985 survey showed a slight increase in destruction: nearly 55 percent of the forest stands were damaged. The worst affected areas are in the States (Lander) of Bavaria and Baden Wurttemberg (home of the Black Forest). Severe damage has also been reported for the Harz, Sauerland, and Eggegebirge mountain areas (2).
   The economic costs of *Waldsterben* are mounting up. In one estimate, West German timber and related industries are losing up to $509 million annually, and damages could go as high as $9–11 billion a year (3). The Union of German Forest Owners, however, calculates the eventual damage at nearly $1 billion a year if present trends continue (4).
2. Switzerland ranks second in damage (in Western Europe) after West Germany. In 1983, 8–14 percent of the country's total forested area was said to be affected by *Waldsterben*. By 1984 this figure had ballooned to a full third (33 percent) of Swiss forests, and 12 million sick trees (representing 14 percent of the total forest area) had to be felled. The worst affected areas are located in the southern alpine cantons of Grisons and Valais, where 50–60 percent of the trees are said to be severely affected (5).
3. Austria has also been badly hit by *Waldsterben*—16 percent of its forests covering 600,000 hectares are reported injured. Austrian authorities are concerned that the country could be stripped of 4.2 million cubic meters of timber a year at a cost of $160 million (6).
4. The Netherlands cataloged the extent of forest damage in December 1984. The survey included 2,800 sites covering an area of 281,000 hectares, or 85 percent of Dutch woodlands. The prognosis was grim: 40 percent showed signs of damage, but forestry officials claimed that about half the damaged trees could recover. Still, 8 percent of the country's forests were in the critical category (7).
5. France also suffers from *Waldsterben*. In mid-1985, the French Ministry of Environment put the total damage in the Vosges region of northeast France at 20 percent; 35,000 hectares were affected with 5,000 hectares in serious condition (8). However, long-term residents in the area claim the damage is more like 80 percent. Says Jean-Paul Ortscheidt, a naturalist from Vosges, "there are no healthy conifers on the forest floor" (9). Furthermore, it has been reported that fir trees throughout Alsace and the Donon Massif have been losing their needles at an unnatural rate for four years (10).
6. Belgium reports that 70 percent of the forests along the border with West Germany are damaged to one degree or another (11).
7. Denmark claims that trees covering 1,000 hectares in west Jutland are suffering from *Waldsterben*-like symptoms (12).
8. Sweden surveyed its southern forests in 1984 and found that 240 forest stands in 11 counties were showing symptoms of decline. The National Swedish Environment Protection Board puts the damage at 10 percent; in other words every 10th tree is injured (13).
9. Great Britain maintains that it has not been affected by *Waldsterben* and reports no official damage to forests. A 1984 survey by Britain's Forestry Commission, however, concluded that 6 percent of the spruce and 20 percent of the Scotch pines were suffering, but attributed the damage to "cold, windy, winter weather" (14). Swedish plant ecologist Bengt Nihlgård visited Britain in the summer of 1985 and reported seeing extensive damage to oak, beech, and ash. He told the *Guardian* newspaper that the symptoms of decline were identical to those in Central Europe (15).

### EASTERN EUROPE AND THE SOVIET UNION

1. Czechoslovakia is the most seriously affected country in Eastern Europe. By 1980, 400,000 hectares of forests were reported damaged (16) and the figure now stands at between 500,000 and 1 million hectares, with 200,000–300,000 hectares said to be completely destroyed (17). A report issued by the Czechoslovak Academy of Sciences (CSAV) entitled "An Analysis of the Ecological Situation in Czechoslovakia" documents frightful damage over wide areas. More than 6,000 square kilometers of the Czech Lands—which constitute 60 percent of the country's land area—are permanently exposed to excessive concentrations of air pollutants; and 24 percent of the forests in this region are injured (18). The list of damage is horrific:
   - Norway spruce are reportedly dying in over 32,000 hectares of forests in the Giant Mountains.
   - Sixty percent of the trees in a 19,200 hectare-section of the Orlicke Hory Mountains were dead by 1980.
   - In the Ore Mountains (Krusne Hory Mountains) of Northwest Bohemia (near the borders with East and West Germany) the damage is so widespread that most of its 85,000 hectares of woodland will be dead by 1990, in just four years (19).

white fir, Scotch pine and European larch (*Larix decidua*) and seven of the most significant broad-leafed trees—European beech, silver birch (*Betula pendula*), European ash (*Fraxinus excelsior*), European alder (*Alnus glutinosa*), common maple (*Acer pseudoplatanus*) and two species of oak (*Quercus robur* and *Quercus petraea*) (6).

The new kind of forest decline observed in North America is distinct from European *Waldsterben*. The "New World" version affects only conifers with each species showing different symptoms. Scientists have investigated at least eight species in North America: white, loblolly, shortleaf, pitch, and slash pines, red spruce, and balsam and Fraser firs (7). (For a comparison of the symptoms of *Waldsterben* in Europe and the new kind of forest decline in North America, see Table 12.2.).

The Federal Republic of Germany (West Germany) has established a *Waldsterben* survey procedure that involves four categories of damage. Every year since 1982, the various provincial governments have conducted a nationwide inventory of the country's forests, ranking them according to the amount of leaves or needles on the tree. It includes the following stages: 0) healthy, less than 10 percent loss of foliage; 1) slight, 11–25 percent loss of foliage; 2) moderate, 26–60 percent loss of foliage; 3) serious, over 60 percent loss of foliage; and 4) death. By this method the affected species can be assigned a damage category so that the advance or retreat of *Waldsterben* can be assessed every year for each species (8). (See Table 12.3.) Variations on this theme are used in other European countries in determining the health of forests and rating the damage.

Figure 12.1 shows the alarming progression of *Waldsterben* from 1983 to 1984 in the Federal Republic of Germany. White (silver) fir is the most seriously affected tree

Czechoslovak scientists attribute the damage to heavy metal fallout, acid rain, and gaseous emissions of sulfur dioxide and ozone. The CSAV report predicted that over 50 percent of the country's woodlands would be injured and dying by the end of the century, if present trends continue (20).

2. Poland is said to be one of the world's most polluted countries (21). In the Upper Silesian Industrial Region (in Southwest Poland), around Krakow and in the Legnica-Glogow copper basin, forests covering 500,000 hectares—6 percent of the total—are reportedly affected by serious dieback, with 200,000 hectares already dead (22).
3. Yugoslavia reports 450,000 hectares of forests damaged, with 50,000 hectares on the critical list (23).
4. The German Democratic Republic (East Germany) does not officially report its forest decline problems. Nevertheless, scientific accounts published in 1980 estimated that at least 350,000 hectares, or 12 percent, of the country's forests were suffering from *Waldsterben* (24). However, recent evidence indicates that the extent of damage may be as high as 2.5 million hectares. The damage is particularly acute in the Erzgebirge Mountains near the Czech and West German border. East German scientists blame gaseous pollutants; namely sulfur dioxide, nitrogen oxides and ozone, in combination with acid rain (25).
5. Romania claims that at least 170,000 hectares of forests are damaged in the western part of the country (26).
6. Hungary reported in the summer of 1985 that 11 percent of its forests—covering 120,000 hectares, along the northern border with Czechoslovakia were injured (27). Over the past three years the damaged timber is estimated at 1.2 million cubic meters, worth more than 1 billion forints ($20 million). Winter damage has seriously affected 10,000 hectares of Scotch pines, which may have been predisposed by pollution. But Hungarian scientists are more alarmed about the increasingly critical condition of their oak forests, which account for 70 percent of the total damage (28). Initial studies have indicated that Hungary's younger oak forests are suffering from a 5 percent reduction in growth rates when compared to older stands. Forest specialists confirm that all kinds of trees besides oaks, are affected, including firs, pines, spruce, beech, and elm. A concerned government has earmarked half of the annual forestry budget of 15–20 million forints ($200,000–300,000) for research into the causes and remedies of forest decline (29).
7. The Soviet Union is known to be experiencing acid deposition over some 900,000 hectares in European Russia, but there are no confirmed reports of forest decline, except near the industrial town of Togliatti and along the Volga River (30). These declines may be due to entirely different factors.

### References and Notes


1. Earthscan, *Earthscan Press Briefing Document No. 41* (Earthscan, London, 1985) pp. 1–9.
2. Federal Ministry of Food, Agriculture and Forestry, *1983 and 1984 Forest Damage Surveys* (Federal Ministry of Food, Agriculture and Forestry, Bonn, West Germany, 1983 and 1984). Note: The 1985 estimates were provided by unofficial sources in the Federal Ministry for Research and Technology.
3. Time, "Turning Green into Yellow," *Time*, p. 40 (January 9, 1984).
4. Federal Ministry for Research and Technology (Bonn, West Germany, 1985). Note: Unofficial estimates based on 1984 data.
5. Bundesamt fur Forstwesen; *Ergebnisse der SANASILVA Waldschadeninentur* (1984).
6. F. Scholz, *Report on Effects of Acidifying and Other Air Pollutants on Forests* (U.N. Economic Commission for Europe, Air Pollution Unit, 1984) pp. 55–56 and Annex Table 1.
7. Dutch Forestry Service, *Forest Decline Survey* (1984); and *op. cit.* 6, Annex Table 1.
8. *Conference proceedings for the Second International Conference on Action Against the Deterioration of Forests and Atmospheric Pollution* (unpublished, Strasbourg, France, June 7–9, 1985).
9. Jean-Paul Ortscheidt, 1985 (personal communication).
10. *Op. cit.* 8.
11. J. McCormick, *Acid Earth* (Earthscan, London, 1985) p. 104.
12. *Ibid.* p. 105.
13. National Swedish Environment Protection Board, 1984 (personal communication).
14. *Op. cit.* 11, pp. 28–29.
15. John Ardill, "Acid Rain Damage to Trees Worse than Thought, Scientist Claims," *The Guardian* (August 10, 1985), p. 2.
16. F. W. Carter, "Pollution Problems in Post-War Czechoslovakia," *Institute of British Geographers Transactions New Series*, Vol. 10, p. 28 (1985).
17. *Op cit.* 11, p. 123; and Czechoslovak Academy of Sciences, *An Analysis of the Ecological Situation in Czechoslovakia* (CSAV, translated by Charter 77, December 1983).
18. *Op cit.* 16, pp. 24–25.
19. *Ibid.* pp. 30–31.
20. *Op cit.* 17.
21. E. Pudlis, "Poland's Plight: Environment Damaged from Air Pollution and Acid Rain," *AMBIO* Vol. 12, pp. 125–126 (1983).
22. *Ibid.*; and *op cit.* 6, Annex Table 1.
23. *Op cit.* 11, p. 131.
24. *Op cit.* 6, Annex Table 1.
25. P. Wensierski, "Wir Haben Angst um Unsere Kinder," *Der Spiegel*, No. 28, p. 73 (July 8, 1985).
26. *Op. cit.* 11, p. 131.
27. Dr. R. Solymos, "The Physical Condition of Our Forests and the Succeeding Tasks," (translated by the Hungarian Academy of Sciences, 1985) pp. 11–12.
28. *Ibid.* p. 12.
29. *Ibid.*
30. S. Postel, "Protecting Forests from Air Pollution and Acid Rain", in *State of the World, 1985* (Norton, New York, 1985) p. 106.

## Table 12.2 Comparison of Symptoms and Possible Causes of Forest Declines in Europe and North America

| Possible Causative Agent | Symptoms | Central Europe | Eastern North America |
|---|---|---|---|
| | **Growth-decreasing symptoms:** | | |
| Foliar Leaching, Ozone, Drought | Yellowing of foliage from the lower to the upper and from the inner to the outer portion of branches—oldest tissues affected first. | Observed mainly in white fir and Norway spruce at high elevation. | Observed in white fir in the San Bernardino Mountains and recently in red spruce in New York and Vermont. |
| Natural Stress, Abiotic and Biotic | Dying back from the top of trees—youngest tissues affected first. | Common in oak and ash, less common in birch and beech. | Conspicuous in red spruce, maple and oak declines; ash and birch diebacks. |
| $SO_2$, Insect Pests, Drought | Increased transparency of crowns due to gradual loss of leaves but with leaves retained to the very top of the trees. | Observed in Norway spruce, white fir, Scots pine, larch, beech, birch, oak, maple, ash, and alder. | Observed only in the littleleaf disease of shortleaf pine and in the beech-bark disease. |
| Fertilization | Losses of fine-root biomass and mycorrhizae (beneficial symbiosis between tree roots and soil fungi). | Common in white fir, Norway spruce, and beech. Not studied in other species. | Observed mainly in red spruce decline, birch dieback, and littleleaf disease. |
| Chronic Ozone<br>Chronic $SO_2$ | Synchronized decrease in diameter growth without other visible symptoms. | Not reported in Europe. | Observed in pitch pine and shortleaf pine. |
| Acute Ozone<br>Acute $SO_2$<br>Foliar Fertilization | Synchronized decrease in diameter growth with other visible symptoms. May result in mortality. | Studied mainly in Norway spruce, white fir, and beech. Not studied in other species. | Observed in red spruce and Fraser fir mainly at high elevation. |
| Heavy Metals, Nutrient Stress | Progressive decrease in diameter growth with other visible symptoms. May result in mortality. | Studied mainly in Norway spruce, white fir, and beech. Not studied in other species. | Observed in ash and birch diebacks, some maple and oak declines, sweet-gum blight, littleleaf disease, and pole blight. |
| Heavy Metals, Organic Substances | Death of herbaceous vegetation beneath some affected trees. | Observed in high elevation spruce and medium elevation beech forests. | Not observed in North America. |
| | **Abnormal-growth symptoms:** | | |
| Organic Substances | Active casting off (abscission) of leaves and shoots while still green. | Common in spruce, fir, beech, ash, larch, and Scots pine. | Reported only rarely in North America, in loblolly pine, red spruce, and Fraser fir. |
| Organic Substances | Change in relative length of long shoots and short shoots. | Common in beech. | Reported only in the mycoplasma induced "yellow" of ash. |
| Ozone | Concentration of leaves and needles at tips of branches in tufts or clumps. | Common in oak and ash. | Observed in nearly all decline of broad-leaved trees and in some conifers. |
| Organic Substances | Change in size and shape of leaves. | Common in beech and birch, occasionally in oak, spruce, and Scotch pine. | Common in white pine, littleleaf disease of shortleaf pine, and some maple and oak declines. |
| Stress | Excessive production of adventitious shoots on branches. | Common in Norway spruce, white fir, and larch. | Observed recently for the first time in conifers. Common in maple and oak, ash, and birch. |
| Stress, N Fertilization | Excessive production of seeds and cones. | Common in spruce, fir, beech, and birch; often observed several years in a row. | Observed in many stressed trees mainly one year at a time. |

**Source:** Bartuska *et al.*, 1985, Reference 21; Cowling, 1985, Reference 20.

## Table 12.3 West German Forest Damage Surveys, 1982–84

| Tree Species | Millions of Hectares 1982 | 1983 | 1984 | Percent of Forests Damaged 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|
| Spruce | .270 | 1.195 | 1.477 | 9 | 41 | 51 |
| Pine | .090 | .641 | .866 | 5 | 44 | 59 |
| Fir | .100 | .135 | .152 | 60 | 75 | 87 |
| Beech | .050 | .326 | .631 | 4 | 26 | 50 |
| Oak | .020 | .090 | .269 | 4 | 15 | 43 |
| Others | .032 | .161 | .303 | 4 | 17 | 31 |
| Total | .562 | 2.549 | 3.698 | 8 | 34 | 50 |

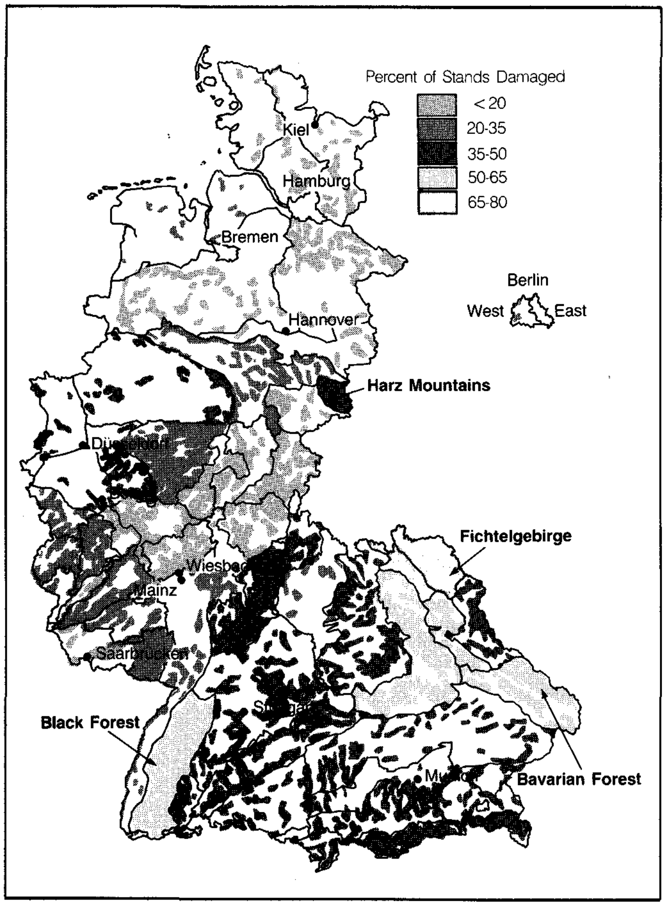
**Note:** Damaged area includes stages 1, 2, 3, and 4.
**Source:** West German Federal Ministry of Food, Agriculture and Forestry, 1984, Reference 8.

species in West German forests, with 87 percent of its stands damaged and Scotch pine is not far behind with 59 percent of all stands affected. In trees 60 years or older the damage is most severe with 95 percent of all white fir, 73 percent of all Scotch pine and 82 percent of all Norway spruce stands showing visible decline symptoms (9).

Furthermore, the severity of the dieback in Europe is escalating as more trees move into the terminal stages of "decline". The 1985 forest survey in West Germany revealed that many trees that showed only mild damage (stages 1 or 2) in 1984 had moved into stages 3 and 4. For most species the period of time between the first symptoms of damage and the stage at which the tree has to be cut varies from a few weeks to three years (10).

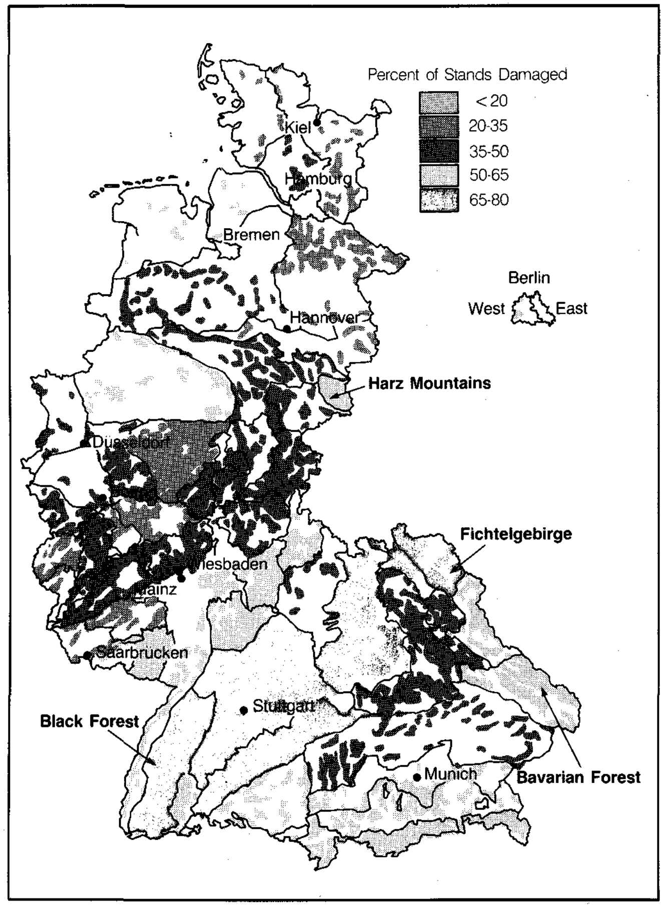
In the Black and Bavarian Forests of southwestern and southeastern Germany, respectively, *Waldsterben* is particularly acute. Both conifers and broad-leafed trees stand stripped of all foliage and some are covered with lichens. Dead, brittle branches litter the forest floor. Other trees, weakened from the "disease" and uprooted by winds, show stunted and deformed root systems. In some cases the fungus roots (mycorrhizae)—responsible for nutrient uptake—are very limited or completely absent. *Waldsterben* seems to affect every part of the tree's physiology. Among those trees still alive, many have lost 60 percent or more of their leaves and needles and will soon perish, finished off by frost, wind damage and insect attacks. Many of the stressed trees attempt to fight off death by shedding leaves and needles while still green, others produce masses of cones or seeds in efforts to reproduce. In parts of the Bavarian forest, even the vegetation beneath the drip line of the canopy is brown and lifeless. It's almost as if the entire ecosystem has been poisoned. As the forests go, so too does the wildlife. Noticeably fewer birds and animals inhabit some *Waldsterben* stricken forests. This same picture is repeating itself across at least

**Figure 12.1A Forest Decline in the Federal Republic of Germany, 1983**




**Note:** Shaded areas represent percent of stands damaged, including all tree species and damage classes 1 to 4.
**Source:** West German Federal Ministry of Food, Agriculture, and Forestry, 1984.

**Figure 12.1B Forest Decline in the Federal Republic of Germany, 1984**




**Note:** Shaded areas represent percent of stands damaged, including all tree species and damage classes 1 to 4.
**Source:** West German Federal Ministry of Food, Agriculture, and Forestry, 1984.

seven million hectares of forestlands in 15 European countries. (See Box 12.1.)

## HISTORIC FOREST DECLINE

Of course, air pollution damage to forests is nothing new. As the Industrial Revolution gathered momentum in the latter part of the 19th Century, many point sources of pollution were responsible for high levels of atmospheric contaminants. Trees and other vegetation have been dying near metal smelters, chemical plants, refineries, and fossil fuel-fired power stations for the past one hundred years or more (11). Forests in Central and Eastern Europe have been suffering periodically from "smoke damage" since the middle of the 19th Century. The "smoke" usually consisted of a toxic concoction of sulfur dioxide, nitrogen oxides, and heavy metals, along with soot, ash, and dust from coal-fired industrial processes, metal smelters, and power plants. However, such damage was usually found close to heavily industrialized, urban areas; it was seldom generalized over entire regions (12).

In recent years the pattern of pollution in Eastern Europe has changed dramatically. Czechoslovakia, in particular, has become very heavily polluted (as documented by the Czechoslovak Academy of Sciences [CSAV]). (See Box 12.1.) Total gaseous emissions jumped from 3.6 million metric tons in 1960 to 7.3 million metric tons by 1980, an increase of more than 100 percent (13). The amount of sulfur dioxide generated in 1980 was 3.2 million metric tons, while 1.6 million metric tons of nitrogen oxides were also produced along with 500,000 metric tons of hydrocarbons (14). "As a result of these various facts," writes F. W. Carter, a geographer at University College, London, "Czechoslovakia is now among one of the most intensely air polluted countries in the world. On average, about eight metric tons of atmospheric pollutants per inhabitant are generated annually and in urban areas the average yearly solid particle emission reaches 500 metric tons per square kilometer (15)." Little wonder that the country's forests, not to mention human population, are under increasing stress from air pollution. The same is true for the heavily industrialized parts of Poland and East Germany, which are known to have large areas of "smoke" damaged forests. In an effort to combat the damage, Poland has been experimenting with pollution-resistant trees for the past 15–20 years.

Gaseous pollutants, like sulfur dioxide, hydrogen fluoride, and ozone, have played prominent roles in past declines, but their destructive effects have been relatively "localized," or limited to specific areas under continuous assault from airborne pollution. As early as 1910–11 damaged trees (mostly lodgepole pine and Douglas fir) were investigated in the Deerlodge National Forest located near the Washoe metal smelter at Anaconda, Montana (U.S.). They were found to be suffering, in part, from sulfur dioxide pollution, which retarded their growth (16). Similarly, ozone has damaged or killed thousands of ponderosa and Jeffrey pines in the San Bernardino Mountains east of Los Angeles, California, a city famous for its yellow-brown photochemical smog. A U.S. Forest Service survey carried out in 1969 revealed that some 1.3 million ponderosa pines growing on 405 square kilometers in the San Bernardino National Forest were stressed and dying (17). In areas with the highest ozone concentrations, timber yield was found to be reduced by 80 percent or more. Today, both ponderosa and Jeffrey pines have been seriously damaged or killed over wide areas in the San Bernardino Mountains, resulting in a markedly altered forest ecosystem.

However, natural stresses like drought, frost, and winter damage (called abiotic factors) along with biotic factors such as insect infestations, fungi, and other disease organisms have probably figured prominently in most large-scale forest declines of the past. Between 1871 and 1880, for example, red spruce forests from New York State to New Brunswick, Canada were devastated by what has since been attributed to a combination of drought conditions and insect attacks (18).

These earlier experiences have led some researchers to assign *Waldsterben* to natural causes, rather than the wide spectrum of anthropogenic pollutants now under investigation on both sides of the Atlantic. Dr. Otto Kandler of the Botanical Institute at the University of Munich believes that *Waldsterben* is due to a mysterious virus imported from Czechoslovakia. "There are several epidemics in our forests," says Kandler, "they are periodic with peaks and troughs. What we have now is the coincidence of several peaks in the old diseases, plus a new one" (19). So far the "virus" has yet to be identified or described in any detail and many researchers are skeptical of the idea that *Waldsterben* is just one more chapter in the familiar book of forest dieback. "We are faced with a very complex problem," says Dr. Claude Martin, Director of the World Wildlife Fund of Switzerland, and "it would be wrong to put forest death down to one cause. It is just as stupid to blame a virus as it would be to say that forests were dying only because people were driving their cars too fast. There are a multitude of factors leading to this situation and we are convinced air pollution is a major one."

The virus view ignores important clues that clearly separate *Waldsterben* from previous documented declines due to biotic or abiotic factors. Historically, most forest damage was limited to one or two agents, or a combination of several; in nearly every case there were visible "smoking pistols." Moreover, the damage was usually localized or, if regional, involved only a few species. Never before has such large-scale and rapidly spreading forest decline been observed affecting so many different species under such varied ecological conditions. Over the past 50 years there have been 19 major or minor regional forest declines in Europe and North America. Of these 19 reported declines, at least seven implicate air pollutants as a primary, or at least a contributory, cause (20). (See Table 12.4.) With one exception, all of the pollution-related declines developed (or at least were noticed) within the last eight years. Increasingly, the finger is being pointed at airborne chemical pollution as the major cause of forest decline and death (21).

## DAMAGE TO FORESTS

*Waldsterben* is, by far, the most complicated and serious forest decline on record. Dr. Peter Schütt, Professor of Forest Botany and Pathology at the University of Munich and Dr. Ellis Cowling, Associate Dean for Research at the School of Forest Resources at North Carolina State University in Raleigh, have produced a comprehensive description of *Waldsterben* (22). The following features of the "disease" and its extent are noteworthy:

1. Visible symptoms of *Waldsterben* began around 1979–80 in many different parts of Europe and within four years the "disease" had spread over large areas of the continent.
2. As of late 1985, *Waldsterben* was still increasing in intensity and geographic distribution and is associated

### Table 12.4 The 19 Major Forest Declines of the Last 50 Years

**Pollution-Related Forest Declines**

Widely assumed major role:

- *Waldsterben* in Europe
- Decline of ponderosa and Jeffrey pines in the San Bernardino Mountains, California
- Regional decline of white pine in the eastern United States and Canada

Possible major role:

- Decline of red spruce, and balsam, and Fraser firs at high elevations in the Appalachian Mountains from Georgia to New England
- Growth decline without other visible symptoms in loblolly, shortleaf, and slash pines in the Piedmont regions of Alabama, Georgia, North and South Carolina
- Growth decline without other visible symptoms in pitch and shortleaf pine in the Pine Barrens region of New Jersey
- Widespread dieback of sugar maples in northeastern United States and southeastern Canada

**Declines Related to Biological or Physical Factors**

- *Tannensterben* (white fir decline) in Europe
- *Kiefersterben* (Scotch pine decline) in East Germany and European Russia during early 1970s
- Oak decline in Germany and especially in France since early 1900s
- Decline of *Pinus pinaster* on the Atlantic coast of France since early 1980s
- Beech bark disease of northeastern United States and southeastern Canada
- Littleleaf disease of shortleaf pine in the southeastern United States
- Birch dieback in the northeastern United States and southeastern Canada
- Poleblight of western white pine in the Rocky Mountains
- Maple decline in the northeastern United States and southeastern Canada
- Oak decline in Pennsylvania, Virginia, and Texas
- Ash dieback in the northeastern United States and southeastern Canada
- Sweetgum blight in the southeastern United States

**Note:** A number of the declines attributed to biological or physical factors might involve toxic air pollutants, but studies are incomplete, and evidence insufficient to make a strong connection.

**Source:** Adapted from Cowling, 1985, Reference 20.

with an alarming frequency of damage from secondary stress factors such as insects, needle and root fungi, and climatic stresses (i.e., frost, wind, and snow damage).

3. Within five years it affected nearly every tree species in central Europe including the four most commercially important conifers (spruce, fir, pine, and larch) and six angiosperms (beech, birch, oak, ash, maple, and alder).
4. Various species of shrubs and herbs have been damaged in certain affected forests.
5. The symptoms are heterogeneous from one region to another, from one stand to another, and even within the same species in the same stand.
6. *Waldsterben* occurs with similar intensity on poor and rich soils, acid and basic soils, and on wet and dry soils, independent of their geological origin.
7. The symptoms often are more severe in higher elevations, but they occur in middle and low elevation sites as well.
8. Different forest management practices and the composition of the forest (i.e., single versus mixed stands, planted vs. natural) do not appear to have a significant impact on the amount of damage.
9. Young trees are normally not as severely affected as older ones, but even this varies from region to region.
10. Some of the typical symptoms have never been described before (especially for beech, spruce, and larch).
11. The worst damage appears in higher elevation forests on slopes facing the prevailing winds.
12. Most of the victims show both growth-decreasing and abnormal growth symptoms (23).

The *Waldsterben* phenomenon is characterized by three broad indicators of destruction: growth-decrease, abnormal growth, and water stress (24). (See Table 12.1.)

Dr. Cowling cautions that although the common symptoms of *Waldsterben* include increased susceptibility to biotic and abiotic stress factors, this dieback pattern is very different from the normal diseases induced by familiar biotic forest pathogens—fungi, bacteria, nematodes, insects, and viruses. "It is also distinct," says Cowling, "from the typical injuries to forests induced by drought and frost, or by gaseous air pollutants like ozone and sulfur dioxide" (25).

A widely accepted conceptual framework summarized recently by Dr. Paul Manion from the State University of New York helps to understand the complex interactions involved in forest declines. In this scheme, stress factors fall into three categories: predisposing, inciting, and contributing (26). Predisposing factors include climate, soil condition (moisture and nutrient supply), long-term atmospheric deposition of pollutants, and the genetic makeup and age of the tree. The effects of predisposing factors are generally asymptomatic. Inciting factors produce visible symptoms of injury. These include such abiotic stresses as drought and frost damage; biotic stresses like insect defoliation; and the short-term impacts from toxic gases (i.e., ozone, sulfur dioxide, etc.). These injure the tree and cause a relatively rapid deterioration of its condition. However, it is the contributing factors that actually "pull the trigger". Because of the interaction of the other two factors of decline, trees become susceptible to severe damage from abiotic stress agents like drought, frost, and wind damage as well as the usual litany of biotic stresses: insects, nematodes, fungi, mycoplasmas, bacteria, and viruses. Most of these agents may have been present always, but had little previous impact until the tree was weakened by predisposing and inciting factors (27). It is also interesting to note the overlapping role played by different stress agents. Drought, for example, can be a factor in all three categories.

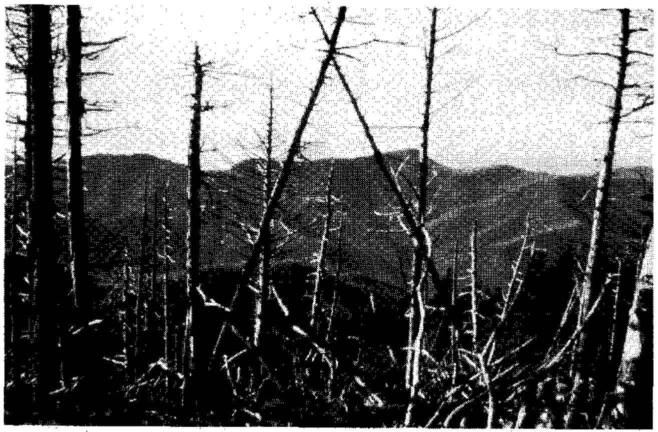
Whether or not Manion's analytical framework can be applied entirely to *Waldsterben* remains to be seen. A number of scientists are convinced that airborne chemical fallout may play a role in all three decline categories—predisposing, inciting, and contributing.

The array of symptoms and the speed with which entire stands are affected suggests that the causes are multiple. *Waldsterben*, along with the North American decline, most certainly cannot be attributed to a single factor or even several factors. Emerging evidence points to the combined effects of a number of pollutants working synergistically, antagonistically, or in an additive manner. "Regional declines of forests on both continents are believed to result from the combined action of several different competitional, biological, physical, and chemical stress factors that act simultaneously or sequentially to induce the symptoms of damage," says Dr. Cowling (28).

The continuing debate swirling around the issue of acid deposition (commonly called acid rain) has, in a certain sense, only added to the muddle over the causes of *Waldsterben*. "When it comes to forest decline," declares Dr. Chris Bernabo, former Executive Director of the U.S. National Acid Precipitation Assessment Program, "the acidity of rainfall is no longer the primary issue. Many pollutants are probably involved in this process" (29).

Given this, the scientific community still continues to debate the role of air pollution and acid deposition in the European and North American forest decline syndromes. Is air pollution only a preconditioning factor? An inciting factor? A contributing factor? Or all three? Is it a primary agent? A secondary agent? Or both? And all this is further aggravated by the fact that so little is known about how forest trees respond to different kinds of stress factors.

Since the symptoms of *Waldsterben* in Europe and the regional declines of certain conifers in North America vary, the research efforts on opposite sides of the Atlantic also differ. Nevertheless, the two forest decline syndromes have a number of instructive, if not disconcerting, similarities. Recent research has revealed that the coniferous forests in both North America and Europe have been under continuous stress for the last three decades. Increment cores taken from thousands of conifers over the past few years show that their annual growth rings have become markedly narrower since 1970 as compared to the 1950s and 1960s. Growth declines of up to 20 percent have been observed in red spruce, and loblolly, shortleaf, and pitch pines in the eastern United States. In an interview with the *New York Times*, Dr. Samuel McLaughlin—



*This dead coniferous forest on Mount Mitchell, North Carolina, is the result of the complex interaction of multiple pollutants.*

a forest physiologist working at the Oak Ridge National Laboratory in Tennessee—said that after examining core samples from 7,000 trees, representing 34 species in 15 states from Maine to Missouri, he had found "a systematic, regionally scaled and sustained decline in the growth of several species over the past 20–25 years" (30). In some severe cases, as on Mount Rogers in Virginia and on Mount Mitchell in North Carolina, the growth rates of red spruce and Fraser firs have been severely stunted. The radial growth of red spruce on Mount Mitchell and a few other sites has decreased an average of 82 percent, a fivefold drop since the 1960s (when compared to the period 1950–60) (31).

In Europe, diameter growth reductions began in white fir about 1960, followed by Norway spruce (circa 1970), and seem to have started in European beech as of 1978–80 (32).

These "invisible" growth symptoms, undetected until recently, occur long before the visible health of the tree begins to break down.

There are other connections too. In both Europe and North America the most severely damaged trees are those found consistently on higher elevation slopes facing the direction of the prevailing air masses, particularly those shrouded in clouds or fog much of the time (33).

Another disturbing aspect of *Waldsterben*—one more piece of circumstantial evidence pointing to air pollution stress—is the fact that mixed stands of trees are more damaged than monocultures. Air currents can penetrate the canopies of mixed forests more easily, while it takes longer for air masses to invade monocultures, where the trees are all roughly the same height (except at higher elevations and in steep terrain). Hungarian research has borne this out as well. Scientists there have even found that during heavy pollution episodes, peculiar kinds of circular air currents are created over mixed forests (34). But in the end, monocultures too succumb to the *Waldsterben* syndrome.

As the evidence mounts up, a growing number of U.S. scientists fear that the eastern forests of North America may soon experience *Waldsterben*-like symptoms over wide areas. "Something very dramatic is happening very quickly to the forests of the eastern United States, especially up the spine of the Appalachian Mountains," notes Dr. Robert Bruck, a plant pathologist at North Carolina State University in Raleigh and Project Leader of the Mount Mitchell study (35).

## THE CHEMICAL ETIOLOGY OF *WALDSTERBEN*

Despite all the scientific squabbling over the causes of *Waldsterben* in Europe and the decline of coniferous forests in North America, there appear to be four broad areas of agreement at least among the scientists working on the air pollution connection. This emerging "consensus," tenuous as it is, involves the following assumptions:

1. Like cancer, *Waldsterben* must be understood as a disease syndrome, induced by multiple factors involving several "predisposing and stress-inducing factors, followed by numerous secondary effects of abiotic and biological origin" (36).
2. The primary causes are not due to insect or known forest pathogens, although these agents do play a secondary role.
3. Climatic factors such as drought or frost may also be involved, but their role is most probably secondary or "predisposing."
4. The atmospheric deposition of air pollutants or pollutant-related toxic, nutrient, or growth-altering substances are among the primary causes. The major air pollutants of concern are listed in Table 12.5.

### Six "Schools of Thought" on Forest Decline and Air Pollution

Six major "schools of thought" or general concepts have evolved over the past five years to explain the role of air pollution in the forest declines observed in Europe (to a certain degree these also apply to North America). These hypotheses are: 1) General Stress; 2) Soil Acidification-Aluminum Toxicity; 3) Ozone and Sulfur Dioxide Injury; 4) Magnesium Deficiency; 5) Excess Nutrient or Excess Nitrogen; and 6) Growth-Altering Organic Chemicals (37).

#### *1. General stress*

This hypothesis was developed by a group of botanists, plant pathologists and physiologists at the University of Munich. According to Schütt, "air pollution and associated atmospheric deposition of nutrient, growth-altering or toxic substances has led, in recent years, to a decrease in net photosynthesis and associated diversion of photosynthate from mobile carbohydrates to less mobile and potentially toxic secondary metabolites" (38). In other words, this process leads to poorer energy status in the tree's root system, coupled to an increase in toxic substances in the shoots. This complex interaction eventually results in the "starvation" of the fine roots and mycorrhizae (fungus roots) as well as loss of needles or leaves. Since the tree's overall energy balance is reduced, it is much more susceptible to other stress agents like drought, frost, and wind, as well as any number of secondary biotic pathogens (39) (just as a starving person of-

**Table 12.5 Chemical and Physical Nature of the Most Common Air Pollutants**

- Sulfur dioxide ($SO_2$): A colorless gas produced during combustion of sulfur-containing fossil fuels (i.e., coal and oil) and during smelting of sulfide metal ores. $SO_2$ is emitted mainly by large stationary sources such as fossil-fuel-fired power plants, metal smelters, and other industrial and commercial installations.
- Nitrogen oxides ($NO_x$): Two colorless gases (NO and $NO_2$) produced in any high temperature processes (i.e., combustion of coal, oil, gasoline, and natural gas). $NO_x$ are emitted by both stationary sources and transportation vehicles.
- Toxic metals: Lead, cadmium, nickel, and other toxic elements (e.g. fluorine) released mainly by large metal smelters and by transportation vehicles using leaded gasoline.
- Volatile organic compounds (VOCs): A wide variety of carbon compounds ranging from such simple molecules as ethylene, gasoline, and cleaning and painting solvents, to complex compounds such as pesticides. VOCs are produced by many different, usually small, stationary, and mobile sources.
- Carbon monoxide (CO): A colorless and odorless but highly toxic gas produced during incomplete combustion of coal, oil, gas, or incineration of garbage and other waste products. Carbon monoxide inhibits respiration in humans and other animals. It is of concern to society mostly in urban areas where it accumulates in stagnant air mainly from transportation vehicles.
- Particulate matter: A catch-all category of pollutants. The substances of concern range from coarse "fugitive dust" particles that cause soiling of textiles, windows, paints, etc., to fine aerosol particles that cause atmospheric haze or are drawn into the lungs where they induce respiratory disease.

  These substances are very diverse, both chemically and physically. The larger particles range from almost pure carbon in the case of soot from oil burners, to mineral dusts in the case of manufacturing facilities that produce cement, asbestos, clay, ceramics, textiles, and other materials. The fine particles range from smoke to all sorts of sulfate ammonium, organic, metallic, and other fine aerosol particles formed by condensation of gaseous and other volatile atmospheric substances. Some of these particles have remarkable and complex fine structures that are characteristic of the original sources of emissions.
- Ozone ($O_3$) and other photochemical oxidants: These substances occur only as secondary pollutants. They are produced when $NO_x$ and VOCs interact with atmospheric oxygen in the presence of sunlight. Ozone is the most important photochemical oxidant. It is one of the most toxic gases to which plants and human beings are exposed in the environment.
- Acid deposition: Acidic and acidifying substances produced when $SO_2$, $NO_x$, and HCl combine with oxygen and moisture in the air to give aqueous solutions or aerosols of sulfuric, nitric, and hydrochloric acids. Acid deposition occurs when these substances are dissolved in rain, snow, hail, dew, and fog (wet deposition). It also occurs by dry depositions of sulfate, nitrate and chloride aerosol particles, and as gaseous $SO_2$, $NO_x$, $HNO_3$, and HCl. The acidic substances in wet and dry deposition may be partially or completely neutralized by alkaline soil elements such as calcium, magnesium, potassium, and sodium, or by ammonium ions. Acidification of aquatic and terrestrial ecosystems also occurs when ammonium sulfate aerosol and other ammonia or ammonium compounds are taken up by plants after deposition into ecosystems.

**Source:** Cowling, 1984, Reference 121.

ten succumbs to some common disease or infection before dying from lack of food).

### *2. Soil acidification—aluminum toxicity*

This hypothesis was advanced by Dr. Bernhard Ulrich and his colleagues at the University of Göttingen, West Germany. The concept rests on Ulrich's long-term studies of nutrient cycling carried out on the Solling Plateau near Göttingen. According to Ulrich, the natural acidification of forest soils (due to a number of processes, including humus disintegration and nitrification) is accelerated by the chronic atmospheric deposition of wet or dry acidic, or acidifying substances (40). Acids drastically alter the chemical structure of soils and plants. In ecosystems subjected to a constant "acid bath," nutrients like calcium, magnesium, and potassium that are essential for growth are eventually leached from the soil by acidified particles, while aluminum (present in all soil) is liberated and becomes toxic. Just as the process of aluminum toxicity, generated by acid rain, kills freshwater fish and other aquatic life, mobilized aluminum in the soil attacks the fine roots of the trees, resulting in necrosis. This, then, leads to increased moisture and/or nutrient stress and eventually to "drying out" and death of the trees, particularly during drought periods (41). Because their root systems are so damaged, the afflicted trees cannot take up needed nutrients from the soil nor enough water to survive. Using this data, Dr. Ulrich predicted the decline of Europe's forests in 1979.

### *3. Gaseous pollutant injury—ozone and sulfur dioxide*

This hypothesis has been advocated particularly by Dr. B. Prinz of the Landesanstalt fur Immissionsschutz in Essen, West Germany. It is founded on many field observations and measurements of ozone and sulfur dioxide concentrations in West Germany as well as on controlled exposures of seedlings to these pollutants alone and in various combinations (42). So far, only the yellowing or browning of needles and leaves have been duplicated in laboratory studies.

Despite the fact that ozone levels are known to be high in many parts of Europe, data on its actual extent and effects are "patchy." In North America, ozone has been identified as a primary factor in the decline of pine forests for the past 20 years.

### *4. Magnesium deficiency*

This hypothesis has been advanced especially by Professor Karl Rehfuess of the Department of Soil Sciences at the University of Munich. It is founded on field observations and both foliar and chemical analyses in spruce stands at high elevations (43). Rehfuess believes that the yellowing of spruce foliage is due to extreme magnesium deficiency, and concludes that "acid deposition... may contribute to these growth disturbances; it adds nitrogen to the ecosystem but may leach out magnesium and calcium from needles and soils. The leaching from foliage is presumably accelerated by episodic ozone or frost damage to cuticles and cell membranes" (44).

### *5. Excess nutrient or excess nitrogen*

This hypothesis is the result of cumulative research over the past 20 years and is based on the premise that with the onset of the Industrial Revolution—and the "mass production" of man-made sources of pollution—forest ecosystems have been receiving excessive doses of the 16 elements considered essential for all plant growth (45). All 16 elements can be taken up by trees through their foliage or roots.

In particular, the atmospheric deposition of nitrogen over wide areas has increased dramatically since the Second World War and could be contributing to the *Waldsterben* syndrome in Europe as well as the forest declines in North America. "Excess nitrogen is known to induce the following detrimental effects," write Schütt and Cowling, "increased growth and hence increased demand for all other essential nutrients may lead to deficiencies of these other elements; inhibition or necrosis of mycorrhizae; increased susceptibility to frost; increased susceptibility to root-disease fungi; changes in root-shoot ratios; and altered patterns of nitrification, denitrification, and possibly nitrogen fixation" (46). In other words, just as crops can be overfertilized and "burn up," so forests can fall victim to "overfertilization" by excessive airborne deposition of nutrients.

### *6. Growth-altering organic chemicals*

This very speculative hypothesis was suggested by Professor Fritz Führ, Director of the Institute of Radioagronomy at Jülich, near Bonn, West Germany. Führ postulates that among the thousands of organic compounds produced every year in Europe and North America, a few of them—singly or in combination—may produce some of the growth-altering symptoms described earlier (47). (See Table 12.1.) Ethylene and aniline are examples of such compounds.

## Air Pollution Damage Mechanisms

Since there is no single hypothesis that can explain all the symptoms of damage observed, ten specific damage mechanisms based on these six "schools of thought" have been postulated to explain the means by which airborne chemicals may contribute to forest declines. (See Table 12.6.) As mentioned before, Table 12.2 compares the symptoms of the forest declines in North America and Europe and links them with possible etiological agents.

### *Ozone Damage*

Ozone ($O_3$) and other photochemical oxidants—including PAN (peroxacetyl nitrate), PPN (peroxyproprionyl nitrate), and hydrogen peroxide—have been known to damage trees and other vegetation in concentrations of as little as 100–200 micrograms per cubic meter ($\mu g/m^3$) for periods of six hours or more extending over several days (48). Ozone damage to crops in the United States has been estimated to cost roughly $1–2 billion a year (49). So far, no monetary figure has been placed on ozone damage to forests, but the eventual price tag could be staggering.

Ozone is formed when nitrogen oxides and volatile hydrocarbons (also known as volatile organic carbon—VOC) react with oxygen in the presence of sunlight, particulary when UV radiation is high. The major sources of these precursor chemicals are fossil-fuel-fired power stations, industrial processes, refineries, vehicle exhausts, and volatilization of organic solvents and fuels. Once in the atmosphere, this chemical "soup" becomes highly reactive.

In central Europe ambient ozone levels vary from 50 to 250 $\mu g/m^3$, and in West Germany hourly mean concentrations ranging from 100 to 250 $\mu g/m^3$ are quite common over wide areas, with peak values reaching 400 $\mu g/m^3$ (50). Over the past 20 years, there has been a clear upward trend in ozone concentrations in both East and West Germany (51). Furthermore, nitrogen oxide emissions—important in the formation of ozone—have increased by 50 percent between 1966 and 1978 in West Germany (52). Similar ozone levels are found throughout the United States.

Figures 12.2 and 12.3 show the major pathways by which ozone may damage trees. The most extensive work on ozone pollution in relation to forest decline has been done in the United States. European research into ozone damage is fragmentary and has usually been done in connection with sulfur dioxide fumigation studies.

Two large-scale studies carried out in the United States are particularly relevant to hypothesis 1 (Figure 12.2), which maintains that ozone directly damages foliar tissues. Both studies conclusively link ozone pollution to forest damage (53). The first—carried out in the San Bernardino Mountains, east of Los Angeles, California—

**Table 12.6 Ten Hypotheses on How Air Pollution Could Cause Forest Decline**

**Hypotheses Involving Direct Effects:**

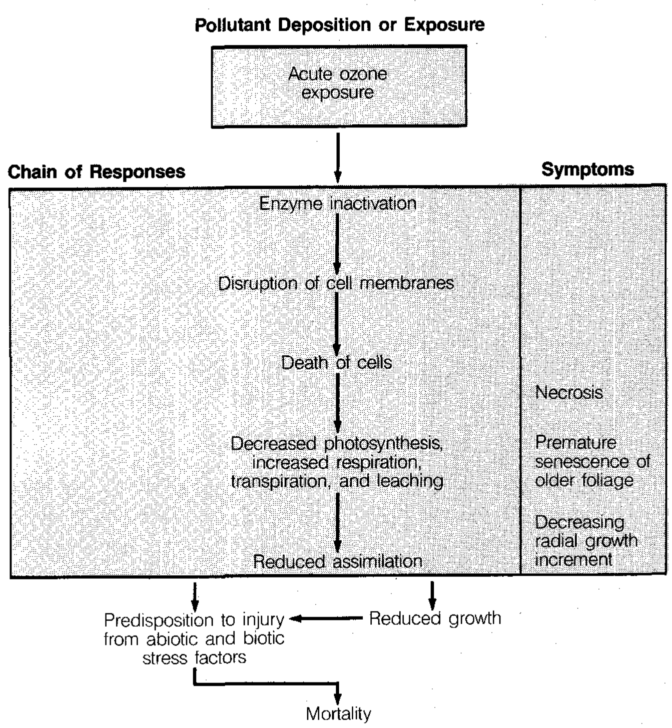
1. Ozone damage and decreased photosynthesis efficiency
2. Ozone damage in combination with acid rain and increased foliar leaching
3. Sulfur dioxide damage
4. Foliar fertilization and increased winter injury (excess nitrogen deposition)
5. Foliar fertilization and altered nutrient allocation (excess nitrogen deposition)
6. Growth-altering organic substances
7. Nutrient leaching from foliage (acid deposition)

**Hypotheses Involving Indirect Effects:**

8. Nutrient leaching from soil (acid deposition)
9. Aluminum mobility and toxicity (acid deposition)
10. Heavy metal toxicity (heavy metal deposition)

**Source:** A. Bartuska *et al.*, 1985, Reference 21.

**Figure 12.2 Hypothesized Pathway Involving Direct Ozone Damage to Foliar Tissue**




**Note:** See Table 12.6, Hypothesis 1.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

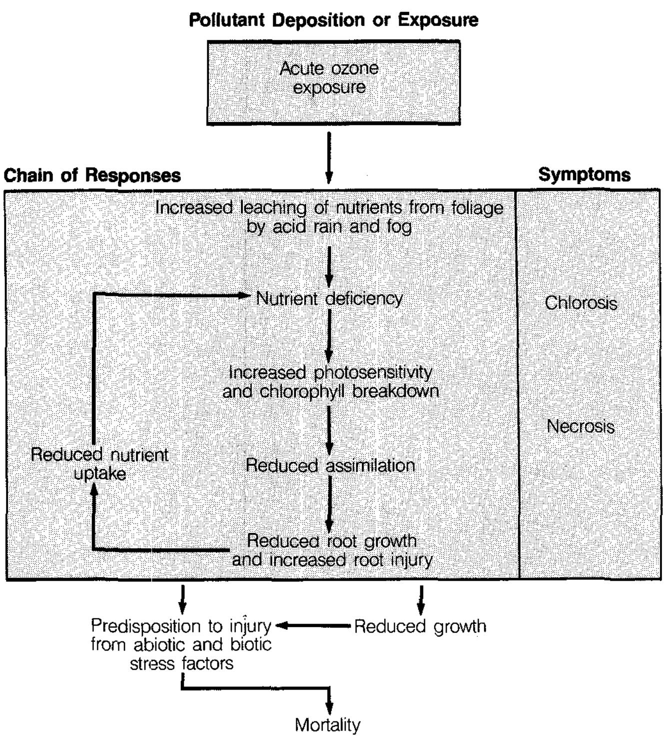
concentrated on ponderosa and Jeffrey pines, American white fir (*Abies concolor*), black oak, and incense cedar, while the second focused on eastern white pine (*Pinus strobus*) in Virginia. The results demonstrated that "ozone induced foliar injury and premature leaf fall, leading to decreased photosynthetic capacity, decreased radial (annual) growth, and reduced nutrient retention in foliage. This weakening of the trees led to increased susceptibility to pine beetles and root rot, thus leading to mortality" (54).

It was stressed, especially in the San Bernardino study, that ozone predisposes the trees to insects, pathogenic fungi, and other biotic agents which finish them off; ozone does not, in itself, kill the trees.

The second hypothesis involving ozone (Figure 12.3, hypothesis 2) suggests that ozone exposure in combination with acid mist or fog increases nutrient leaching from the leaves or needles, and the resulting nutrient deficiencies (e.g., magnesium and calcium) reduce photosynthesis and biomass production both in the canopy and in the root systems (55). This loss of magnesium may account for the yellowing of spruce needles commonly seen in West Germany, since magnesium plays a central part in the structure of the chlorophyll molecule, as iron does in hemoglobin. The loss of magnesium and calcium from the leaves causes the roots to work overtime to replace these crucial nutrients, and the resulting transfer of these nutrients from the soil increases the hydrogen-calcium ratio in the soil, and hence the acidity. The major evidence comes from studies coordinated by Dr. Prinz and colleagues in the North-Rhine Westphalia region of West Germany. Field observations and analysis showed that all age classes of Norway spruce and white fir are affected, but lab experiments could duplicate only the characteristic mottling and chlorosis of needles in spruce, not white fir (56). Although it is known that ozone together with acid rain is a nasty combination, so far field observations have not been successfully duplicated under controlled conditions.

Ozone in combination with acid deposition (and heavy metals) may also be playing a major role in the deterioration of Hungary's forests. Dr. R. Solymos, head of the Forestry Department in the Ministry of Agriculture, states that the serious oak decline observed in Hungary is due to this combination, which "fosters the aridity noticed in the oaks, causing trees to die from the top down, with yellowing of the leaves and complete shedding of bark. This, in turn, leads to the appearance of fungal pathogens and insects which dispatch the trees in short order" (57).

**Figure 12.3 Hypothesized Pathway Involving Ozone Damage and Accelerated Foliar Leaching**




**Note:** See Table 12.6, Hypothesis 2.

**Source:** Adapted from A.M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

### *Sulfur dioxide damage*

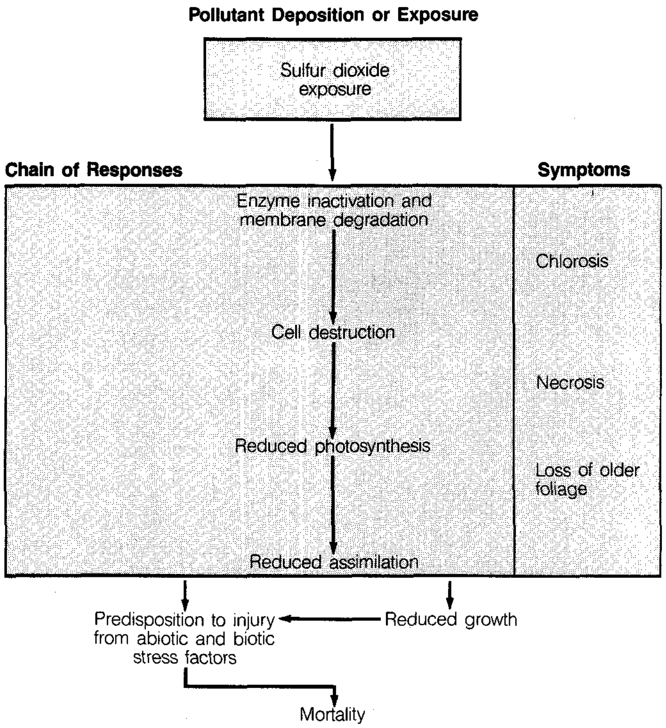
Gaseous sulfur dioxide ($SO_2$), a product mainly of the combustion of fossil fuels in power plants and industrial processes, is a potent pollutant even before mixing in the atmosphere with nitrogen oxides to form acid rain. Somewhere between 110 and 115 million metric tons of $SO_2$ are emitted across Europe (including Eastern Europe and the USSR) and North America every year (58). Despite this tremendous amount of pollution, acute $SO_2$ damage to forests is limited to areas surrounding major point sources. Nevertheless, a vast literature has grown up around $SO_2$ injury to trees and vegetation in the vicinity of power plants, metal smelters, and other polluting industries.

It has been well established that $SO_2$ injures trees by entering the stomata (pores) in the leaves or needles, where it reacts with water to form sulfuric acid, which collects in a thin film on the cell walls. The results are easy to spot: the leaves on deciduous trees take on a "bleached" look, while the needles on conifers turn red-brown.

Figure 12.4 (hypothesis 3) details the pathway by which acute exposure to $SO_2$ causes alterations in enzyme activity and cell destruction within leaf and needle tissues, resulting in physiological changes and reduced growth (59).

$SO_2$ pollution has also been linked to overall reduction in radial growth and, in some severe cases, death of nearly all vegetation near heavily polluting industries. The classic example of point source $SO_2$ pollution is the Inco metal smelter in Sudbury, Ontario (Canada)—the largest single source of sulfur dioxide pollution in the world (650,000 tons per year, more than Sweden's total output). Complete mortality of vegetation was reported in an inner zone of 1,865 square kilometers surrounding the smelter (60). Similar "tree graveyards" have been observed

**Figure 12.4** **Hypothesized Pathway Involving Sulfur Dioxide Damage to Foliar Tissue**




**Note:** See Table 12.6, Hypothesis 3.
**Source:** Adapted from A. M. Bartuska, *et al.*,"The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

in southern East Germany and northwestern Czechoslovakia, where $SO_2$ and "smoke" damage is extensive (61).

However, the typical symptoms associated with $SO_2$ damage have not been found in West German forests, except where connected to an identifiable point source. Average annual $SO_2$ concentrations in pollution-damaged West German forests range from 7 to 21 grams per cubic meter ($g/m^3$), well below the permanent damage level which begins at almost 40 $g/m^3$ (62). Given this fact, Professor Rehfuess has advanced the notion that $SO_2$ damage in Central Europe may be due to chronic stress brought on by low level doses over a long period (63). It should be noted, however, that peak half-hour mean concentrations can reach 1,000 $\mu g/m^3$ or more, even in "clean air" regions in Central Europe (64).

### *Excess nitrogen-nitrate-ammonia deposition*

Of the 16 elements considered essential to forest growth, nitrogen is generally regarded as the most critical nutrient regulating optimal forest productivity. Experimental evidence suggests that if more nitrogen than usual is available, the tree takes up the added nitrogen, thereby increasing its need, proportionally, for other important nutrients. If they are not available, then the tree's normal physiology is disrupted (65).

The main anthropogenic source of nitrogen is agricultural fertilizers, but it also originates from sewage sludge treatment, from chemical fertilizer plants, and (a very small amount) from vehicle exhausts. In Europe about 70 percent comes from agricultural land (and sewage treatment) and 10–20 percent from natural sources (66).

Fertilizer use is massive throughout the developed world. In Sweden, for example, the average application of nitrogen-based fertilizers is 80 kg per hectare per year. North American studies have found that 10 percent of all applied doses of nitrogen fertilizers evaporate into the atmosphere. In Sweden, it has been estimated that every year some 25,000 metric tons of nitrogen go up, while over 80,000 metric tons come down as wet deposition alone, pointing to substantial transboundary transport (67). Futhermore, across wide areas of Central Europe and the midwestern United States, 10–25 kg/ha/year of nitrogen falls in wet plus dry deposition (in West Germany the range is 15–30 kg/ha/year) (68). By contrast, in "clean" unpolluted areas deposition is less than 1 kg/ha/year (69).

However, in the higher elevation spruce-fir forests of the northeastern United States, total atmospheric nitrogen is estimated to be as high as 37–44 kg/ha/year, with at least half of it coming down as wet deposition (70).

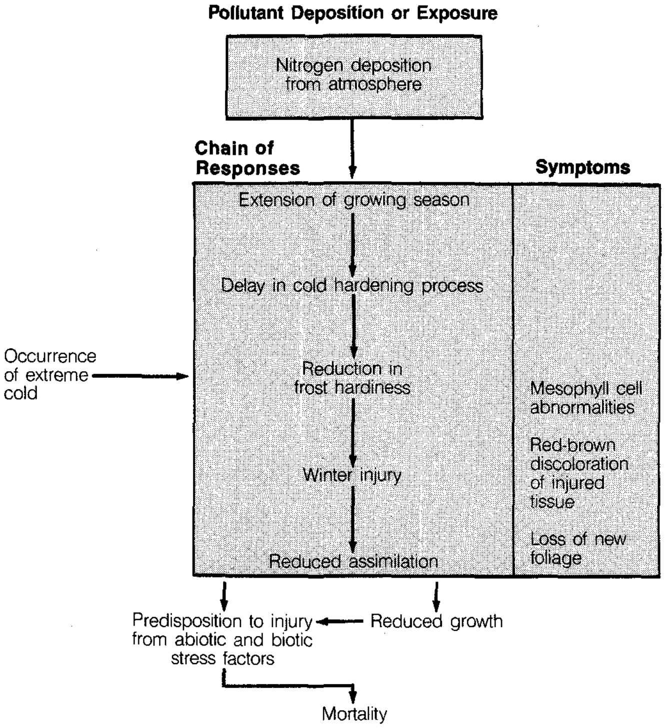
There are two hypotheses as to how excess nitrogen-ammonia deposition harms forests (Table 12.6): through increased fertilization of foliage, leading to more winter damage (Figure 12.5) and through excessive fertilization of foliage in combination with altered nutrient allocation within the trees' metabolic system (71). (See Figure 12.6.)

The mechanism of destruction illustrated in Figure 12.5 is straightforward: in a sense, excess nitrogen stimulates the tree into extra growth activity, thereby prolonging the growing period, so that the trees do not have enough time to prepare for winter (72). Normally, trees and shrubs must go through a cold-hardening process in autumn, when they essentially stop growing and undergo important metabolic changes (somewhat akin to hibernating animals). Too much nitrogen at this critical stage, and the adjustment process is totally disrupted.

The visual symptoms of damage include red-brown discoloration of the needles and needle loss in spring. These symptoms have been observed in Central Europe and in higher elevation sites in the United States from North Carolina to Vermont.

The second nitrogen hypothesis (Figure 12.6) links excess nitrogen deposition to changes in the allocation patterns of carbon and other nutrients within the plant, predisposing the tree to lethal secondary pathogens like nematodes, fungi, and insects (73). Because increased nitrogen overstimulates the tree, causing it to take up greater quantities of other nutrients, the tree soon depletes its soil mineral reserves. In order to compensate for this, the tree's overall root mat system eventually shrinks, making it susceptible to drought in summer and wind-throw in winter. Overfertilization of nitrogen by even 10 percent above normal levels is enough to affect the feeder root systems (ectomycorrhizae) of some trees, as well as rendering the trees more palatable for insects (74).

**Figure 12.5 Hypothesized Pathway Involving Foliar Fertilization by Nitrogen and Reduction in Frost Hardiness**




**Note:** See Table 12.6, Hypothesis 4.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Citing Swedish research, Bengt Nihlgård, a plant ecologist at the University of Lund, has surmized that "nitrogen-saturated forests would begin to appear after 20–25 years if the nitrogen deposition rate was in the range of 30 kg/ha/year" (75). Much of Europe and some high elevation sites in North America are already approaching such levels.

### *Growth-altering organic substances*

Professor Fritz Führ at Jülich has added this ingredient to the *Waldsterben* stew. "No one knows about the role of organic chemicals in forest death and this is a critical area," insists Führ. "Today, some 1.5 million tons of organic chemicals—pesticides, herbicides, and thousands of others—are released across the Federal Republic every year. Some of these may interfere with the tree's hormone production system and other processes" (76). Dr. Peter Schütt agrees: "in one study we found traces of 400 organic compounds in one cubic meter of ambient air" (77).

Hypothesis 6 (Figure 12.7) may be rather speculative, but there is at least one instance linking the atmospheric deposition of synthetic organic compounds to the abnormal growth symptoms seen in West Germany (and on Mount Mitchell, North Carolina). The chemical, aniline, has been implicated in the rapid mortality of loblolly pines near a chemical plant not far from Raleigh, North Carolina. Major symptoms include browning of needles, shedding of needles while still green, and death of mature trees (78).

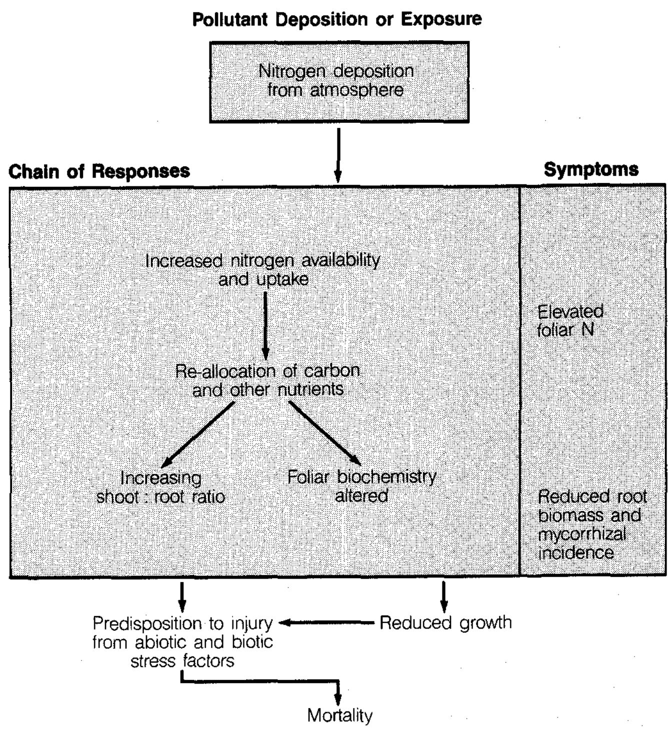
Ethylene is also known to affect plant growth, causing leaf abscission (shedding of leaves and needles) in concentrations as low as 0.1 gram per liter of air (79).

Auxin, an important plant hormone, has also been linked to leaf curling and distortion of leaf blades or needles; in higher concentrations it is used as a herbicide. Professor Schütt speculates that two chemicals may come together in a binary fashion (80)—like chemical warfare agents—forming a highly toxic substance in very small quantities. This hypothesis needs the most attention, as little has been done, to date, to show how organic chemicals (particularly those used in the manufacture of herbicides and pesticides)—singly or combined—may play a role in forest decline and death.

### *Acid deposition*

Acid deposition is a combination of sulfur dioxide and nitrogen oxides together with hydrogen chloride and

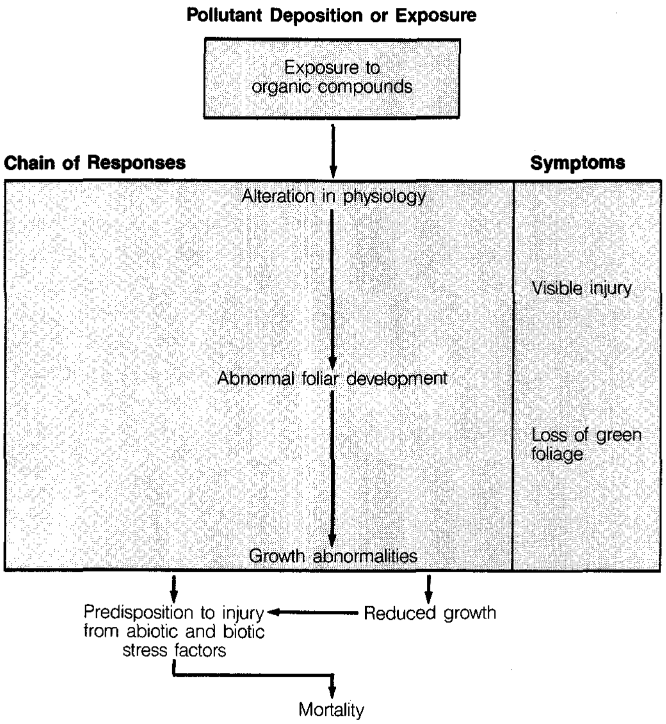
**Figure 12.6 Hypothesized Pathway Involving Changes in Nutrient Allocation Patterns as a Response to Increased Nitrogen Availability**




**Note:** See Table 12.6, Hypothesis 5.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

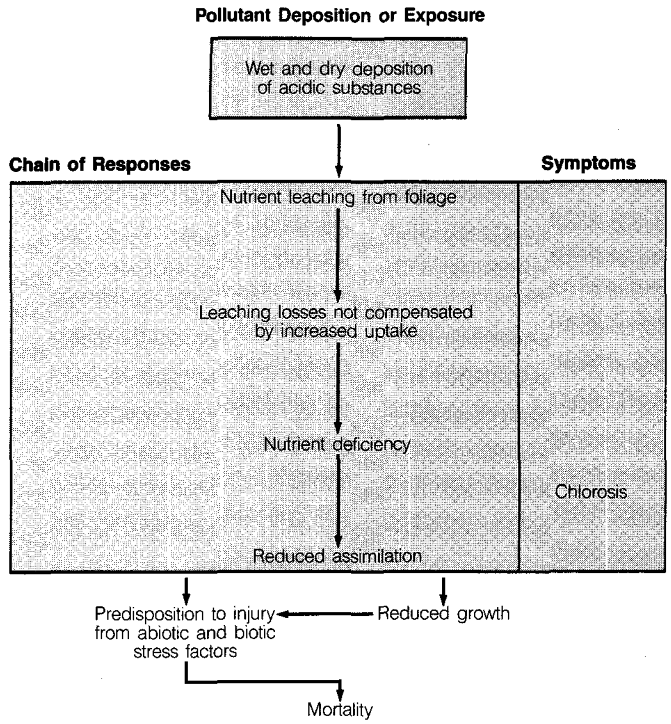
**Figure 12.7** Hypothesized Pathway Involving Growth Altering Substances and Altered Physiology




**Note:** See Table 12.6, Hypothesis 6.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

**Figure 12.8** Hypothesized Pathway Involving Foliar Leaching and Nutrient Imbalance




**Note:** See Table 12.6, Hypothesis 7.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

other compounds which mix in the atmosphere with oxygen and water vapor to form dilute solutions of strong mineral acids. These substances then fall to earth as acid rain, snow, or fog, or as acidified dry particles. Acid deposition originates mainly from fossil-fuel-fired power stations and industrial processes, although $NO_x$ comes about equally from vehicle exhausts. (See Table 12.5.)

Foliar leaching is considered a normal part of the tree's nutrient cycling system and does not inherently pose any threats to health. However, the tree's critical internal clock, or nutrient balance, must be maintained. A number of studies in North America have shown that acid precipitation in the range of pH 2.3–5.0 leached potassium, calcium, and magnesium from the leaves and needles of sugar maples, yellow birch, and white spruce (81). Despite the fact that many forest ecosystems in Europe and North America regularly receive up to 30 times more acidity than is deposited in unpolluted, "pristine" environments, so far there is no evidence that foliar leaching affects overall productivity and growth.

Figure 12.8 (hypothesis 7) shows the pathway by which essential plant nutrients, particularly base cations, are removed from leaves and needles at an accelerated rate due to acid deposition. (See Table 12.6.) Ozone's role in leaching nutrients from foliage has already been discussed.

Research on 194 forest sites in southwestern West Germany demonstrated that trees attempt to compensate for foliar leaching by taking up more nutrients from the soil (82). If nutrients are not available, the trees are more susceptible to climatic stresses.

Dr. Bernhard Ulrich, the main proponent of hypotheses 8 and 9, contends that acid deposition accelerates normal soil acidification processes. Ulrich's work on the Solling Plateau has demonstrated that acid deposition does leach essential nutrients from the soil, at the same time mobilizing aluminum, which then damages the root systems (83).

Figure 12.9 (hypothesis 8) shows the pathway through which plant nutrients are leached from the root zone of the soil by acid deposition. As discussed previously, soil acidification is a natural process that takes place in most soils in humid climates.

However, this entire process is very site specific. Soils with high buffering capacities—like much of the U.S. Midwest, which sits atop limestone or sandstone formations—are not as affected by acid deposition as are those soils found above thin glacial tills or thick granitic bedrock (as in much of Scandinavia, Canada, and parts of

Central Europe). In other words, thin soils with restricted root zones are more vulnerable to the effects of acid leaching than richer, deeper soils with higher concentrations of buffering agents like calcium and potassium. Another factor to consider is that each tree is different. Individual trees, like people, react differently to environmental stresses.

The third part of this acid rain "trilogy" (Figure 12.10) shows how acid deposition may mobilize phytotoxic concentrations of aluminum in the soil, which then kills the fine feeder roots. During spring snow melts, soils also experience acid "pulses" in which great quantities of aluminum and other heavy metals are liberated at the same time, soaking into soils and leaching into water courses. Dr. Ulrich found that aluminum concentrations of as little as 1–2 milligrams per liter (mg/l) in soil solutions could damage root systems (84). At Solling, he found 6 mg of aluminum per liter under beech forests and 15 mg of aluminum per liter under spruce forests, well above his threshold levels for injury (85).

On the other hand, Norwegian research carried out by Abrahamsen and Tveite suggests that concentrations of aluminum must be 80–160 mg/l in solution before damage to roots is evident (86). The wide differences in findings have been swept aside as "site specific." Says Ulrich, "soils with reserves of calcium are not as affected by mobilized aluminum as soils with less buffers" (87).

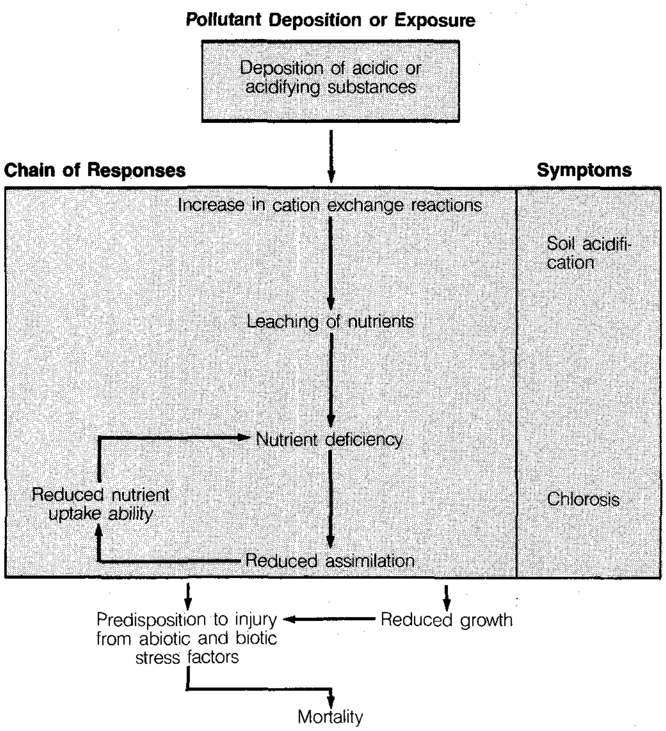
Soil acidification and aluminum toxicity appear to be problems in some parts of Europe, where middle- to higher-elevation spruce-fir forests are found on mineral soils, with poor buffering capacities. By contrast, the higher elevation forests in the eastern United States are mostly found on organic soils. For this reason, U.S. scientists place acid rain much farther down the list of possible causes of forest decline than is the case in Europe.

### *Heavy metal deposition*

Heavy metals in the atmosphere result from the combustion of fossil fuels in power plants and industry and from the smelting of metal ores, although leaded petrol (gasoline) is also a major source of airborne lead.

Elevated levels of lead, cadmium, copper, and zinc, in particular, have been found in forest litter and soils at higher elevations throughout the Appalachian chain up to New England. As much as 2 grams of total lead per square meter of forest floor (up to ten times normal concentrations) have been found at Camel's Hump, Vermont, and at Mount Mitchell, North Carolina (88).

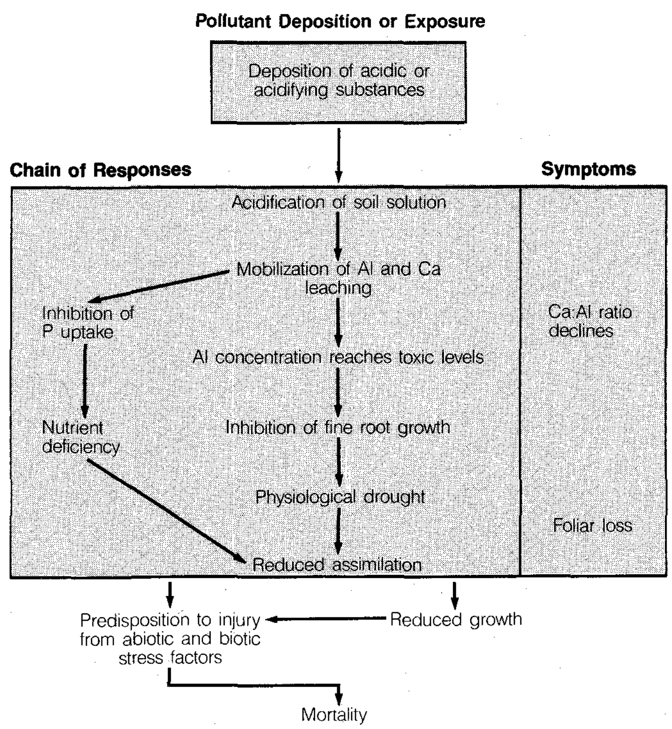
**Figure 12.9 Hypothesized Pathway Involving the Development of Nutrient Deficiencies in Trees Due to Excessive Cation Leaching from Soils**




**Note:** See Table 12.6, Hypothesis 8.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

**Figure 12.10 Hypothesized Pathway Involving Aluminum Toxicity and Forest Species Response**




**Note:** See Table 12.6, Hypothesis 9.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

Andrew Friedland, from the University of Pennsylvania, discovered 200 mg of lead per gram of soil in the forest litter on Camel's Hump, where 70 percent of the red spruce on the west slopes shows serious damage (89). Comments Friedland, "lead is raining down here at the rate of 700 grams per hectare, but it is not being taken up by the trees; most of it remains in the soil where it interferes with microbial processes" (90).

U.S. Environmental Protection Agency studies indicate that lead can inhibit root growth and root elongation at levels between 3 and 10 grams per gram of soil (91). But the worst effects from toxic metals may be more indirect and much more insidious over the long term.

Dr. D.R. Jackson and coworkers found that heavy metals are indeed mobile (particularly when combined with acid rain) and contribute to increased nutrient leaching. However, Jackson concluded, "soil nutrient cycling processes are more sensitive to heavy metal contamination than plant assimilation processes" (92). Apparently, beneficial soil microorganisms, especially fungi and bacteria, are inhibited by heavy metals and fail to break down organic matter into the nutrients trees need, thus altering normal biogeochemical cycling patterns.

It is also known that soil acidity has a profound effect on the mobilization and utilization of lead, as well as other heavy metals. In controlled studies, soil microorganisms exhibited marked metal toxicity as the soil pH was lowered (93).

Hypothesis 10 holds that atmospheric deposition of heavy metals interferes with normal plant functions. Figure 12.11 shows the pathway whereby heavy metals may interfere with both plant and soil microbial processes.

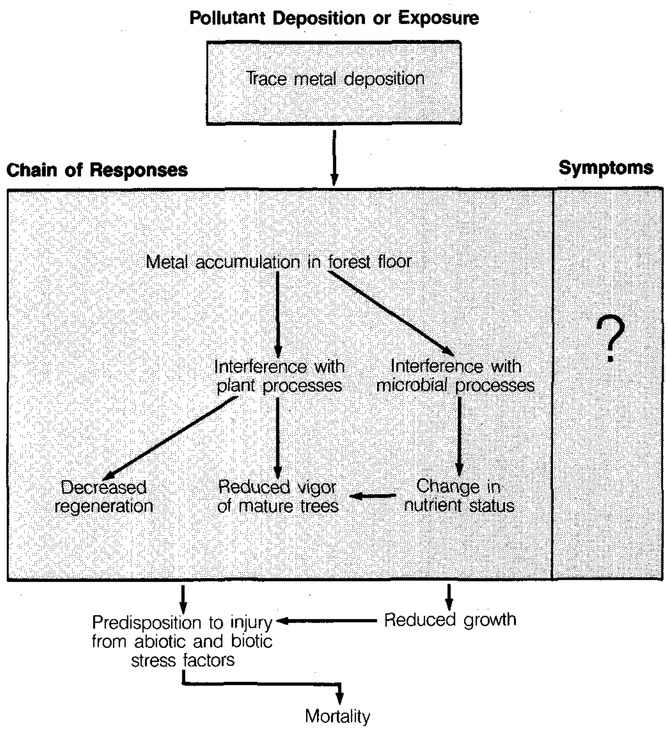
So far, West German research has not been able to find phytotoxic quantities of lead or other heavy metals in soils of *Waldsterben*-affected forests. But this does not mean that heavy metals do not play a role. The North American work on heavy metal contamination of forests is much more thorough than European efforts. Heavy metals may be working together with other pollutants to create multiple simultaneous stresses to forest ecosystems at specific sites over wide areas.

## Ranking the Suspects

As the research programs in Europe and North America begin to narrow down the field of suspects, it is apparant that the agents of destruction vary from region to region and even from stand to stand in the same area. Since there are important regional and even local differences in the symptoms of *Waldsterben*, the mix of causal factors gets shuffled around from one place to another. In this decline syndrome, nothing remains constant. Researchers find the clues shifting from under them as they try to compare the data from different sites.

Nevertheless, a scientific consensus is emerging as to the primary etiological agents. (See Table 12.7.) Since biotic and abiotic factors are considered, by and large, to play secondary roles, only pollutants are included on the lists. As is evident, the North American picture differs from the forest decline in Eastern and Western Europe. The same major pollutants are thought to be at work, but in different orders of magnitude and importance.

**Figure 12.11 Hypothesized Pathway Involving Heavy Metal Toxicity**




**Note:** See Table 12.6, Hypothesis 10.

**Source:** Adapted from A. M. Bartuska, *et al.*, "The Role of Air Pollution in Forest Decline: Hypothesized Mechanisms of Response," *Journal of Environmental Quality* (submitted, 1985).

## THE BURDEN OF RESEARCH

The West German research programs are the most extensive and heavily funded in Europe. Official estimates put the total research effort in the Federal Republic at roughly 300 projects on both federal and state levels, soaking up about DM 205 million (deutsche marks) a year (US $68 million) (94).

The Federal Ministry for Research and Technology (the main coordinating ministry), in an effort to correct the helter-skelter approach to forest decline research, has designated two centers as focal points for its official work on the biological effects of *Waldsterben*. Both centers—KFA at Jülich, outside Bonn, and GSF at Munich—although primarily nuclear research establishments, have departments or institutes that have been active in environmental research for some years. In 1985, Jülich administered DM 29 million of the Ministry's research funds and supervised 64 research groups (95). GSF in Munich works with 11 other institutes and is the headquarters for a series of elaborate chamber studies, where seedlings are being subjected to a variety of airborne chemicals, singularly and in combination, under varying climatic conditions, in an effort to see if any more of the classic *Waldsterben* symptoms can be duplicated in the laboratory (96). Despite the obvious limitations of such studies (it is difficult to duplicate nature in a test tube), if more symp-

**Table 12.7 Airborne Pollutants that May Play Significant Roles in the Forest Declines Observed in North America and Europe**

**North America**

*(ranked in order of importance)*

- Ozone
- Total biologically available nitrogen compounds. This includes wet and dry deposition of all biologically available gaseous, aerosol, and dissolved or suspended forms of nitrate nitrogen ($NO_3$- and $HNO_3$ vapor), ammonia nitrogen ($NH_3$), and ammonium nitrogen ($NH_4{+}$)
- Other phytotoxic gases, including nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), fluorine (Fl), and both peroxacetyl nitrate (PAN) and peroxyproprionyl nitrate (PPN)
- Toxic metals, especially lead, cadmium, zinc, and copper
- Nutrient and acidity-determining cations and anions in wet and dry acid deposition, including potassium, sodium, magnesium, calcium, hydrogen, nitrate, sulfate, phosphate, and chloride
- Growth-altering organic chemicals such as ethylene and aniline

**Note:** This list is biased toward low elevation forests. If it were to include only high elevation forests, the order of importance would change. Nitrogen saturation would come first, followed by heavy metal fallout, ozone and other photochemical oxidants, and acid deposition.
**Source:** A. Bartuska *et al.*, 1985, Reference 21.

**Western Europe**

- Ozone
- *Acid deposition, particularly acid mists and fog*
- Other gaseous pollutants such as nitrogen oxides and sulfur dioxide
- Excess nitrogen deposition
- Growth-altering organic chemicals

**Source:** A. Bartuska *et al.*, 1985, Reference 21; and Peter Schütt, 1985 (personal communication).

**Eastern Europe**

- Gaseous pollutants like sulfur dioxide and nitrogen oxides
- Ozone and other photochemical oxidants
- Acid deposition, particularly acid mist and fog
- Heavy metals

**Note:** Since the declines in Eastern Europe are due generally to the classic pollutants, sulfur dioxide plays a much more important role.
**Source:** Compiled by World Resources Institute from various sources.

toms can be reproduced under controlled conditions, then perhaps the twisted knot of cause and effect can be unraveled, at least a little.

Closely linked to the lab work is an extensive field research program. This is concentrated in four regions: the low mountain ranges of northern Germany; the Schwarzwald (Black Forest) in southwest Germany; and the Fichtelgebirge and Bayerischer Wald in Bavaria (southeastern Germany) (97).

In the first region (low mountains of northern Germany), research efforts are focusing on the connection among pollution deposition, soil acidification, and the changes generated in soil biology and root formation. Supplemental studies include: influence of atmospheric pollutants on changes in ground vegetation, soil biology, and microbial decomposition processes in the soil.

Research efforts in Region 2 (Black Forest) are concentrating on "silvicultural measures aimed at prevention and therapy (e.g., fertilization and thinning) as well as their effects on the development of tree stocks, metabolism, humus layers and fine root systems." The following pollutants are also being measured: $SO_2$, $NO_x$, $O_3$, and PAN.

In Region 3 (Fichtelgebirge), efforts are concentrated on questions regarding soil chemistry, plant nutrition, and whole plant physiology. In addition, fertilization experiments are being carried out along with gas-exchange studies (water status, transpiration, and photosynthesis) on badly damaged spruce.

The fourth part of the research program (Bavarian Forest) is centered on the development of remote sensing methods for the identification and categorization of damage. The end result will be a "balance sheet" of the structure and nature of affected stands. Soil studies are also underway to shed light on the influence of gaseous $SO_2$ on sulfur accumulation in the soil (98).

The official program is well underway with the first comprehensive results expected in two years. There are fringe benefits to such a large-scale centrally coordinated research program—West German scientists are being forced to work in interdisciplinary teams, something they are unaccustomed to doing. It has been recognized that the traditional piecemeal methods of scientific investigation will not suffice. When it comes to *Waldsterben*, only a comprehensive ecosystem approach is most likely to yield useful data. Comments Dr. Bernhard Rami of the Ministry for Research and Technology, "since the combination of pollutants is more damaging than individual elements, we have multiple teams of researchers—air chemists, soil scientists, water specialists, plant physiologists, meteorologists, and plant pathologists—working on the problem" (99).

Since 1980, increased evidence of forest damage in Europe and North America has led to a rapid expansion of research in this crucial area. The U.S. Forest Service and the Environmental Protection Agency (EPA) have formed a joint research program under the umbrella of the National Acid Precipitation Assessment Program. This newly established effort will channel an initial $4.8 million into two major initiatives: 60 percent has gone for research on northeastern forests—to be administered by the Northeastern Forest Experimental Station (U.S. Forest Service); the remaining 40 percent supports research on southeastern forests, supervised by the Southern Appalachian Research Resource Management Cooperative (SARRMC). The research is concentrating on spruce-fir forests in the Northeast and Southeast; commercial pine forests in the Southeast, and mixed hardwood forests in the Northwest and Southeast. In fiscal year 1986, the funds will nearly double to $8 million, $4 million for each center (100).

The research plan has three major goals:

1. "To characterize and describe the current state of forests where air pollution effects are suspected to occur (as well as control areas) and to search for possible correlations of damage by airborne pollutants;
2. "To develop conceptual models of the cause and effect relationships between forest damage and air pollutants, and to use those conceptual models to design experiments, and then implement them to test different hypotheses of damage; and
3. "To refine and develop quantitative models of stand dynamics to predict the responses of forest stands under different air quality scenarios and to extrapolate the current responses of forests across broad spatial regions" (101).

What this means is that specific research efforts must do two things within the general framework: 1) characterize the ecosystem-at-risk, including determination of the quality and quantity of deposition, analysis of key site variables like soil condition, tissue chemistry, pests and pathogens, and a complete documentation of site history; and 2) institute field and greenhouse experiments to identify plant responses to various airborne pollutants and other variables like climate—both singularly and in combinations (102).

In addition to the $4.8 million research package, another $2.5 million has been earmarked for a National Vegetation Survey (coordinated by the Forest Service) that will attempt to assess the extent of productivity losses and visual symptoms of decline in U.S. forests thought to be at risk from air pollution (103). The program will also establish long-term monitoring plots to serve as "early warning stations."

Perhaps most important of all, there is general agreement among scientists that after the initial research, attention will have to shift more toward the combined or additive effects of "multiple pollutants." And these "interaction studies" will require, by far, the greatest output of effort and money as the search for the causes of the North American and European forest declines moves into its final phases.

## SEEING THE TREES THROUGH THE FOREST: GRAPPLING WITH THE POLICY IMPLICATIONS OF FOREST DECLINE

It stands to reason that a disease syndrome as complex and widespread as *Waldsterben*, requires a comprehensive and multi-staged response.

So far, the international response to the threat of continued transboundary airborne chemical pollution has been neither comprehensive nor multi-staged. Since "acid rain" is still regarded as the grim reaper of the environment—thereby ignoring dozens of other harmful chemical compounds—control efforts have centered on sulfur dioxide, and to a certain extent, on nitrogen oxides. It is increasingly clear that whatever combination of pollutants is killing North American and European forests, they are not the same agents that are acidifying lakes and streams in those same countries. Important as it is to control acid rain because of its deadly effects on freshwater resources, terrestrial ecosystems, and the built environment, it should be recognized that battling the agents of forest decline is a much more complicated and far-reaching process. West German scientists investigating *Waldsterben* have identified as many as 160 different possible causative factors (104).

There is little doubt that sulfur dioxide and nitrogen oxide emissions are enormous, but they are only part of the problem. In 1980, roughly 115 million metric tons of anthropogenic sulfur dioxide were belched into the northern hemisphere by the industrialized countries in Western and Eastern Europe (including the USSR), Scandinavia, and North America. (See Table 12.8.) That same year, nitrogen oxide emissions totaled 21–23 million metric tons for the United States, 1.8 million metric tons for Canada, and 9–10 million metric tons for Western Europe (105). Unlike sulfur emissions, which are expected to drop

### Table 12.8 The Twelve Largest Producers of $SO_2$ and Sources, 1980

| | Annual $SO_2$ Emissions (thousands of metric tons) | Sulfur Deposition (percent) | | |
|---|---|---|---|---|
| | | Foreign | Domestic | Undecided |
| **Top Twelve** | | | | |
| USSR | 25,000 | 32 | 53 | 15 |
| United States | 24,100 | | | |
| China | 12,000 | | | |
| United Kingdom | 4,680 | 12 | 79 | 9 |
| Canada | 4,516 | 50[a] | 50 | |
| East Germany | 4,000 | 32 | 65 | 3 |
| Italy | 3,800 | 22 | 70 | 8 |
| France | 3,270 | 34 | 52 | 14 |
| West Germany | 3,200 | 45 | 48 | 7 |
| Czechoslovakia | 3,100 | 56 | 37 | 7 |
| Yugoslavia | 3,000 | 41 | 51 | 8 |
| Poland | 2,755 | 52 | 42 | 6 |
| EEC Total | 17,596 | | | |
| **Others** | | | | |
| Spain | 2,730[b] | 18 | 63 | 19 |
| Hungary | 1,633 | 52 | 42 | 4 |
| Finland | 595 | 55 | 26 | 19 |
| Sweden | 496 | 58 | 18 | 24 |
| Norway | 137 | 63 | 8 | 29 |

**Notes:**
a. Rough estimate
b. 1985 data
**Source:** Data from EMEP, 1981; and the U.N. Economic Commission for Europe (ECE), 1982.

significantly by 1995, nitrogen oxides are projected to increase still further by as much as 25 percent for North America and 5–21 percent for Western Europe by the year 2000 (106).

The progress made in Europe to curtail $SO_2$ emissions to date is due in large measure to the U.N. Economic Commission for Europe's (ECE) Convention on Long Range Transboundary Air Pollution (LRTAP). Signed in Geneva in 1979, the Convention did not come into effect until March 1983, but as of April 1985, 30 countries had ratified it (including the United States and the USSR) (107). Although the LRTAP has been criticized for not having real teeth—until recently it had no timetable for reducing $SO_2$ emissions—the Convention has been credited with beefing up Europe's pollution data gathering network: there are now 88 monitoring stations operating in 23 countries (108). Transboundary pollution issues were given a badly needed nudge during the 1982 Stockholm Conference on the Acidification of the Environment. At this critical meeting it was concluded that anthropogenic emissions of sulfur and nitrogen compounds were primarily responsible for acid deposition, that a decrease in emissions over large industrialized regions would lead to an "approximately proportionate" decrease in acid deposition, and that the technology was already commercially available to radically reduce pollution loads (109).

The Stockholm Conference was also noteworthy in that the West German Government announced a major policy shift: literally, from putting the brakes on further pollution abatement efforts to stepping on the accelerator by insisting on new and much more comprehensive control legislation. The reason was simple: reports that West Germany's forests were dying from air pollution, and the subsequent political fallout prompted the "change of heart" in Stockholm.

As part of the Nordic initiative to speed up compliance with the ECE Convention, delegates from ten countries gathered in Ottawa in 1984 and agreed to reduce $SO_2$ emissions by at least 30 percent by 1993 (using 1980 emissions as the baseline). Some countries even agreed to higher reductions. (See Table 12.9.) The group was dubbed the "30 Percent Club," and as of April 1985, 19 countries had agreed to lower their emissions of sulfur, along with unspecified reductions in other pollutants, mainly nitrogen oxides (110).

At Helsinki in July 1985, LRTAP was finally given some real substance. A protocol mandating definite $SO_2$ reductions of 30 percent by 1993—under the same terms as the 30 Percent Club—was opened for signature. It was immediately signed by the 21 members (representing 19 countries) of the 30 Percent Club, giving it more than enough signatories to bring it into force in October 1985 (111).

Still, two of the largest emitters of both $SO_2$ and $NO_x$, Great Britain and the United States, refused to sign the protocol on the grounds that scientific uncertainty made further reductions problematic.

The European Economic Community (EEC) has also been moving to reduce pollution loads in member countries. In 1983, the Commission of the European Community proposed a Council Directive calling for significant cuts in three categories of polluting emissions by 1995: 60 percent reduction for $SO_2$, 40 percent for $NO_x$, and 40 percent for dust. Large fossil-fuel-burning power stations were the main targets (112).

Such plants account for more than 80 percent of $SO_2$ emissions and 40 percent of $NO_x$ emissions within the European Community. The Commission calculated that additional costs for the slated reductions would be less than 10 percent of total production costs (113). The OECD estimated that the damage from acid rain alone costs the European Community somewhere between $1.4 and $4.2 billion a year (114).

The Commission has also recommended that all member countries switch to unleaded petrol by 1989 and that catalytic converters (with U.S. standards) be in full use within the Community by 1995 (115).

In June of 1985, at the urging of West Germany, the Commission met to discuss the adoption of U.S. emission standards on all new vehicles throughout the Community. Typically, resistance from the other three big car producers—Italy, France, and Great Britian—scotched plans to introduce more stringent, U.S. type controls on motor vehicles. The resulting compromise placed emission controls only on larger vehicles (two liters or more). As of 1988, all large new cars will have to be fitted with catalytic converters and will not be permitted to emit more than 25 grams of carbon monoxide, 6.5 grams of hydrocarbons, and 3.5 grams of $NO_x$ per test. Small (under 1.4 liters) and medium-sized vehicles (1.4 to 2 liters) will be regulated beginning in 1992, but these constitute the bulk of Europe's road traffic. Lead-free petrol will have to be available throughout the Community by 1993, but its introduction will begin much earlier (116).

Disappointed with the outcome, West Germany decided to step up its own program of pollution abatement. New legislation provides tax incentives for those who are willing to retrofit their cars with catalytic converters, and unleaded petrol introduced in 1984 will be commonplace by 1988 (117).

West German regulators have not stopped with mobile sources of pollution; emissions from fossil-fuel-fired power plants and industrial complexes will also be reduced. By the early 1990s, $NO_x$ and $SO_2$ emissions will be slashed by 70 percent (over 1980 levels): $SO_2$ will drop from 3 million metric tons (1982) to 1.2 million metric tons by 1993, while $NO_x$ will go from 1 million metric tons (1982) to 0.3 million metric tons by 1993 (118).

Officials are even considering imposing speed limits of 80–100 km/hr on the autobahns (freeways) to reduce pollution. But this is a highly emotive issue. "Autobahn speed limits arouse the same kind of passions in West Germany as gun control laws do in the United States," noted the *New York Times* in 1984. Regardless of the state of Germany's forests, imposing speed limits is likely to be a long and difficult route.

Despite this impressive record of recent regulations, the Federal Republic is still plagued by the anomaly of Buschhaus, a huge coal-fired power station at Helmstedt near the East German border. Commissioned in April 1985, the plant burns lignite with a high sulfur content (3.5 percent). Each year its 307-meter-high stack will emit 125,000 metric tons of $SO_2$, or 18 metric tons per hour (119). For technical and "legal" reasons, it was allowed to operate virtually without pollution controls, even though the country is clearly making important strides in reducing pollution loads.

Important as all these steps are in bringing pollutants "under the heel" of regulation, how far such agreements as the 30 Percent Club and LRTAP will go toward solving even the problem of acid deposition is uncertain. In any case, there will be no noticeable changes for ten years; it will take that long for control measures to have a major impact. There is also inbuilt government inertia when it comes to implementing and paying for pollution control

**Table 12.9 The 30 Percent Club, as of May 1985[a]**

| | Date of Accession | Exceptions |
|---|---|---|
| Austria | June 1983 | |
| Canada | June 1983 | 50% by 1994 |
| Denmark | June 1983 | 40% by 1995 |
| Finland | June 1983 | |
| Federal Republic of Germany | June 1983 | 50% by 1993 |
| Norway | June 1983 | 50% by 1994 |
| Sweden | June 1983 | |
| Switzerland | June 1983 | |
| France | Mar. 1984 | 50% by 1990 |
| Netherlands | Mar. 1984 | 50% by 1995 |
| Belgium | June 1984 | |
| Bulgaria | June 1984 | |
| Byelorussia (Soviet Socialist Republic) | June 1984 | |
| German Democratic Republic | June 1984 | |
| Liechtenstein | June 1984 | |
| Luxembourg | June 1984 | |
| Ukraine (Soviet Socialist Republic) | June 1984 | |
| USSR | June 1984 | |
| Czechoslovakia | Sept. 1984 | |
| Italy | Sept. 1984 | |
| Hungary | April 1985 | |

**Note:** a. Membership has agreed to reduce $SO_2$ emissions by 30 percent of the 1980 levels.
**Source:** Earthscan, 1985, Reference 2.

technologies. Reducing air pollution is still regarded as an unnecessary economic sacrifice, hampering development and growth.

The existing quagmire of conflicting national laws and policies spills over into regional (i.e., European Economic Community) or international attempts at curbing emissions of polluting substances. Current national and international controls on pollution are inadequate to deal with the array of airborne chemicals responsible for forest dieback and death. Such inadequacy is reinforced by scientific uncertainty and indecision, which in turn fosters frustration and paralysis at the policy level. This "vicious circle" is made infinitely more complicated by the transboundary nature of air pollution, especially since national control policies will, in many cases, have only a cosmetic effect.

This is certainly true for North America, where Canada and the United States are locked in a dispute over the issue of acid rain. Canadians claim that many of their 50,000 acid sensitive lakes and stands of dying sugar maples are damaged by pollution imported from the United States.

Because of the Clean Air Act, the United States is ahead of Europe and Canada when it comes to controlling emissions from vehicles; two-way catalytic converters, which reduce emissions of hydrocarbons and carbon monoxide (but not $NO_x$), and low lead petrol have been required since 1975. Lead-free petrol will be required in 1986. Great efforts have also been made to control emissions from stationary sources. Despite the Tennessee Valley Authority's (TVA) successful effort to cut its $SO_2$ emissions in half (about one million tons), further progress to curtail national emissions has been put in the slow lane, especially in regard to the retrofitting of fossil-fuel-fired power plants in the Midwest. And it is these emitters—particularly the belt of large coal-fired power plants running through Indiana, Ohio, and Pennsylvania—that are sending their polluting gases over the Canadian border.

With little hope for a bilateral agreement to reduce polluting emissions, the disgruntled Canadians have taken unilateral action to at least put their own house in order. In March 1985, Canada announced that it would halve its domestic $SO_2$ emissions by 1994 (from 4.6 million to 2.3 million tons) at a cost of around $300 million. At the same time, officials decided to reduce $NO_x$ emissions by introducing new vehicle emission standards (equivalent to those in the United States) to be effective beginning September 1, 1987. Unleaded petrol is already available in Canada, but a complete switch is planned for sometime in 1988 when catalytic converters will be required on all new vehicle models (120).

Dr. Ellis Cowling of North Carolina State University has drawn up a list of scientific generalizations regarding air pollution and its various effects that bear directly on policy decisions: 1) combustion of fossil fuels is the single most important source of air pollutants; 2) the concentration and deposition of primary air pollutants decrease progressively with increasing distance and time after emission from any particular source; 3) the concentration and deposition of secondary pollutants are a complex function of meteorological, seasonal, altitudinal, temporal, geographical, and other factors; 4) the elapsed time between emission and deposition varies with the pollutant in question but ordinarily ranges from a few minutes or hours to a maximum of four or five days; 5) this time is sufficient to disperse pollutants over both short distances (0–500 km) and long distances (500–2,000 km); 6) for these reasons no state or province can control the quality of air within its own borders without cooperation by other nearby states or provinces; 7) the atmosphere over most industrial regions is very well mixed and the distance between most sources of air pollution is much smaller than the average distance of dispersal from any given source; 8) thus, pollutants rarely, if ever, occur alone—they frequently react with each other forming new chemical products that can be additive, synergistic, or antagonistic in their effects; 9) for many pollutants with biological effects there is no distinct "threshold dose" or safe concentration below which we are certain there will be no adverse effects; 10) therefore significant decreases in emissions of $SO_2$, $NO_x$, and hydrocarbons (VOC) are very likely to have significant and simultaneous beneficial effects on human health, visibility, materials damage, surface water quality, and both crop and forest productivity (121).

This implies a rather broad-based approach to pollution control involving the reduction of emissions from both stationary and mobile sources. Cowling's view was supported by a contribution from Dr. Ann Bartuska, of North Carolina State University, to the latest *Assessment of Acid Deposition and Its Effects*. The report concluded that sulfur dioxide is not the only airborne chemical that is injurious to the environment, and that "if ozone and/or biologically available nitrogen compounds and/or toxic metals prove to be among the airborne chemicals that have significant detrimental effects on forests, it may be desirable to decrease regional emissions of nitrogen oxides and volatile organic compounds either simultaneously with or independently of future changes in emissions of $SO_2$" (122).

Current control strategies throughout much of Europe, while dealing successfully with $SO_2$ and to some extent with $NO_x$ from stationary sources, have almost totally ignored volatile organic hydrocarbons, organic chemical compounds, heavy metals, and nitrogen-ammonia deposition from both stationary and mobile sources. The United States, on the other hand, has successfully lowered vehicle emissions of hydrocarbons, lead, and $NO_x$, but has been prevented by political considerations from further controlling the emissions of these same substances from power plants and industrial processes. Having reduced $SO_2$ emissions by an impressive 36 percent between 1973 and 1983, U.S. policy-makers are now stalled. The Reagan Administration has consistently delayed attempts to further reduce current $SO_2$ pollution loads.

Dr. Bartuska highlighted the dilemma that forest death and decline poses for policy-makers: "1) atmospheric depositions of biologically available nitrogen compounds and heavy metals are more likely to be important in high elevation rather than low elevation forests, and 2) ozone, either alone or in combination with other toxic gases, is the chemical most likely to be important in low elevation forests" (123).

What this means is that no single pollutant control strategy is likely to be effective in dealing with forest decline—it will take nothing less than a total integrated mix of strategies and technologies, tailored for each region, to significantly improve air quality in Europe and North America.

From a technological point of view, a package of controls must be developed and put in place. The technologies for reducing harmful emissions of pollutants are, by and large, already on the shelf. Like any sensible shopper, policy-makers will have to select the right combination of these technologies for the greatest impact at the least cost.

## Technological Solutions to Political Problems

There are many technological routes to take in reducing airborne pollution; the big stumbling block is the cost and social consequences of their actual introduction. In Western Europe and North America, broad-based political considerations often override environmental concerns.

### *Fuel switching*

One of the simplest methods of reducing $SO_2$ pollution is to switch to fuels with a lower sulfur content. The sulfur content in fossil fuels varies from 0.2 to 5.5 percent by weight. Switching from a high sulfur coal, for example, to a lower sulfur coal can have immediate benefits for the environment (124). Such a policy does, of course, have harmful economic impacts in regions mining high sulfur coal.

### *Coal cleaning*

In a number of countries, particularly Scandinavia, Japan, and the United States, coal is physically and chemically pre-treated to remove some of the sulfur. The process is well established and rather inexpensive. Physical cleaning, which includes grinding and washing, adds only $4–9 per ton to the price of coal in the United States (125).

### *Oil desulfurization*

This is a widely applied method and is similar to coal cleaning in that it is also a pre-combustion technique. The oil is pre-treated with hydrogen, which partially removes the sulfur by combining with it to form hydrogen sulfide gas (126).

### *Flue-gas desulfurization (FGD)*

FGD is a post-combustion process that involves spraying the hot exhaust gases with lime or limestone before they are blown up the stack. Commonly referred to as "scrubbing," the process involves the injection of lime, either wet or dry. It combines with the sulfur to form gypsum, which can then be sold as roadbed filler or for other construction purposes. This technology is well developed; there are about 1,000 plants equipped with FGD worldwide, 100 of them in the United States (127).

### *Fluidized bed combustion*

Although this technique has been in use for some time, the latest advances are noteworthy. New fluidized bed boilers burn not only all kinds of fossil fuels but a wide variety of bio-fuels as well (i.e., peat, garbage, wood wastes, sawdust, etc.). The newer models are extremely fuel efficient—with combustion efficiencies of almost 99 percent—and are able to remove 80–95 percent of $SO_2$ and $NO_x$ with significant cuts in heavy metals as well. This is done *in situ* by the injection of lime or limestone into the combustion bed.

The Limestone Injection Multi-Staged Burner (LIMB) is an example of technology developed in the United States to burn multi-fuels and remove multiple pollutants, although there are other versions of this under development, or already commercially available, in Europe and Japan. LIMB has been estimated to cost $30–40 per kilowatt (128).

### *Decreasing nitrogen oxides*

Nitrogen oxides can be decreased in power plants and industrial processes through fairly well established technologies: using low $NO_x$ burners, modifying boilers, and through selective catalytic reduction (SCR) of $NO_x$ in the combustion gases (also called "fuel gas treatment").

Since vehicles contribute 40–80 percent of all $NO_x$ emissions (depending on the country), it is imperative that all cars be fitted with three-way catalytic converters (which, in turn, require very low lead or lead-free petrol in order to function). Catalytic converters, in combination with combustion modifications in engine design, can greatly decrease $NO_x$, carbon monoxide, and hydrocarbons in vehicle exhaust. The new three-way catalyst now under development can decrease these pollutants by 90–95 percent, but its general introduction is still several years away. Another technological breakthrough—the Lean Burn Engine—is estimated to reduce $NO_x$ by 75–90 percent, but it will not be commercially available for about ten years (129).

## WHAT MUST BE DONE

Although it appears unlikely that a generally agreed upon public consensus about decreasing emissions of major pollutants, other than lead, will emerge during the next 2–3 years, two general points remain clear:

1. The American and European policy debates about sulfur dioxide have obscured the importance of other pollutants—namely hydrocarbons, heavy metals, $NO_x$, organic chemical compounds, and other secondary toxic gases like ozone and PAN. All of these warrant increased regulatory attention.
2. Acid rain has been used as a catchall phrase by environmentalists pressing for changes in pollution control strategies and by governments as an excuse to do nothing or very little. This continuing controversy camouflages the real picture: pollution has multiple causes and multiple effects, acidification is just one of many.

The search for a way out of the maze is complicated by inconsistent and inadequate monitoring methods that generally look at only one or two pollutants, like $SO_x$ or $NO_x$, differences in the interpretation of data, and an absence of coordinated research between countries. This is made worse by intramural bickering among different scientific camps as to the exact relationship between pollution and environmental damage. Furthermore, the debate has often been tainted by nationalism, with scientists falling prey to assessments colored by national interests. Great Britain and the United States are prime examples of this tug-of-war between science fact and science fiction.

At present, the path recommended by the Commission of the European Community is probably the best model for tackling the specter of multiple pollutants and resulting forest death. The speed of implementation may be too slow, but the program, if eventually adopted, is comprehensive and transboundary. In order to control pollutants, countries need integrated approaches. The following measures need to be legislatively worked out and implemented by the early 1990s:

1. Three-way catalytic converters should be fitted on all new passenger cars, thereby necessitating the widespread introduction of lead-free petrol. In some cases, like West Germany, speed limits may also be required. (This, of course, does not apply to the United States.)
2. New emission standards for refineries, petrochemical complexes, and chemical fertilizer plants to lower emissions of hydrocarbons and other organic chemicals, as well as airborne nitrogen compounds.
3. Stricter controls on fossil-fuel-fired power stations. New plants should have lower stacks, and multi-staged combustion burners and/or fuel-gas cleaning processes that eliminate not only $SO_2$, but also $NO_x$, heavy metals, and particulates (i.e., dust, soot, ash, etc.).

In the interim period, fuel switching should be encouraged.

4. Stricter controls on metal smelters that produce high amounts of $SO_2$ and particularly heavy metals like lead, cadmium, zinc, copper, and nickel.
5. Setting standards for the application of nitrogen fertilizers on agricultural land and in forests.

All of these measures require more research and a rigorous cost-benefit analysis. Although the actual mechanisms of destruction may never be completely understood, in a few years, scientists will know much more about the role of air pollutants in the growth and development of forests, and will be in a better position to make more specific recommendations. By introducing comprehensive measures to decrease emissions of $SO_2$, $NO_x$, and VOC, in efforts to control forest decline, policy-makers will also be improving the situation as regards to human health, materials destruction, acidification of lakes and rivers, and polluted air in general.

To achieve these multiple benefits it is vitally important that these recommendations be dealt with as a package—the "one pollutant at a time" regulatory approach will not suffice to tackle the problem in time. Money will have to be spent where it will do the most good. This may mean that certain heavy point sources of pollution in sensitive areas must be identified and controlled more than others. As for Europe, it is critical that a continent-wide switch to catalytic converters and lead-free petrol be carried through as planned. The big hitch is that Eastern Europe—particularly East Germany, Poland, and Czechoslovakia—lack the hard cash to invest in many of these measures. So transboundary pollution will continue to be a nagging and perhaps even a bitter issue, dividing Eastern and Western Europe. The same is true for North America where the United States and Canada are at loggerheads over transboundary pollution and acid rain.

No doubt the costs for such a long-range and integrated program will be high. The U.S. Office of Technology Assessment (OTA) estimates that reducing sulfur dioxide emissions by nearly half (10 million tons) from existing sources, would cost \$3–4 billion a year, increasing electricity rates by 2–3 percent. If $NO_x$ were figured in, the costs might be as high as \$6 billion a year (130).

The solution may ultimately depend on narrowing the dichotomy between rhetoric and reality, on persuading governments to invest in sound environmental management plans, and on balancing short-term interests against long-term policy. It also depends on recognizing that although the costs of controlling pollution are high, the costs of not doing so could well be astronomical. It's a matter of whether we start spreading the burden around now, or leave the costs and consequences to our children.

## References and Notes


1. P. Schütt and E. Cowling, "Waldsterben—A General Decline of Forests in Central Europe: Symptoms, Development, and Possible Causes," *Plant Disease*, Vol. 69, No. 7, pp. 448–458 (1985).
2. Earthscan, *Earthscan Press Briefing Document No. 41* (Earthscan, London, 1985) p. 3.
3. *Ibid.*
4. *Op. cit.* 1, pp. 448–458.
5. *Ibid.*
6. *Ibid.* pp. 448–458.
7. A. Bartuska, *et al.*, *1985 Assessment of Acid Deposition and its Effects* (NAPAP, submitted, Washington, D.C., 1985), Chapter 3, p. 10; and EPA, U.S. Forest Service *et al.*, *A Research Plan and Budget for the Southern Commercial Forest Research Cooperative* (1985), p. II.B-1. Note: A. Bartuska's draft paper is used here, since the final published version of the 1985 Assessment was not available when this book went to press. Page numbers refer only to the draft (unpublished) version.
8. Federal Ministry of Food, Agriculture and Forestry, *1984 Forest Damage Survey* (Federal Ministry of Food, Agriculture and Forestry, Bonn, West Germany, October 1984) pp. 2–11.
9. *Ibid.* p. 19 (Table 13.7.)
10. *Op. cit.* 1.
11. W. Smith, "Evidence for Effects of Air Pollution on the Northeastern Forest," in *Air Pollutants Effects on Forest Ecosystems* (Acid Rain Foundation, St. Paul, Minnesota, May 8–9, 1985) p. 123.
12. *Ibid.* p. 124; and W. Smith, *Air Pollution and Forests: Interactions Between Air Contaminants and Forest Ecosystems* (Springer-Verlag, New York, 1981) pp. 333–334.
13. F. W. Carter, "Pollution Problems in Post-War Czechoslovakia," *Institute of British Geographers Transaction New Series*, Vol. 10, No. 1, p. 19 (1985).
14. *Ibid.*
15. *Ibid.* p. 20.

16. W. Smith, *Air Pollution and Forests: Interactions Between Air Contaminants and Forest Ecosystems* (Springer-Verlag, New York, 1981) p. 299.
17. *Ibid.* pp. 314–315.
18. *Ibid.*
19. New Scientist, "German Tree Deaths Blamed on Virus," *New Scientist*, August 15, p. 17 (1985).
20. E. Cowling, "Comparison of Regional Decline of Forests in Europe and North America: The Possible Role of Airborne Chemicals," in *Air Pollutants Effects on Forest Ecosystems* (Acid Rain Foundation, St. Paul, Minnesota, May 8–9, 1985) pp. 219–221. Note: Ellis Cowling lists only 18 forest declines. The extra decline comes from the author's own assessment, using recent data from Environment Canada, indicating that the sugar maple decline in southeastern Canada and northeastern United States is due, in part, to acid deposition.
21. A. Bartuska, *et al., 1985 Assessment of Acid Deposition and its Effects* (NAPAP, draft contribution, Washington, D.C., 1985) Chapter 3, p. 63.
22. *Op. cit.* 1.
23. *Ibid.*
24. E. Cowling, "Acid Rain and Forest Productivity," *Reach Magazine,* St. Regis Paper Co., p. 8 (1985).
25. *Op. cit.* 1.
26. P. Manion, "Factors Contributing to the Decline of Forests, A Conceptual Overview," in *Air Pollutants Effects on Forest Ecosystems* (Acid Rain Foundation, St. Paul, Minnesota, May 8–9, 1985) pp. 64–65; and A. Bartuska, *et al.*, op. cit. 21, pp. 3–4.
27. *Ibid.*
28. *Op. cit.* 20.
29. Dr. Chris Bernabo, 1985 (personal communication).
30. Philip Shabecoff, "Scientists See Forests Declining in Eastern United States Due to Pollution," *International Herald Tribune*, (February 29, 1984), p. 6.
31. R. Bruck and W. Robarge, "Decline of Boreal Montane Ecosystems in the Southern Appalachian Mountains," *Journal of Water, Air, and Soil Pollution* (submitted), 1985.
32. Peter Schütt, 1985 (personal communication).
33. E. Cowling, "Regional Declines of Forests in Europe and North America: The Possible Role of Airborne Chemicals" (unpublished, 1985) p. 11; and *op. cit.* 31, pp. 16–19.
34. Dr. R. Solymos, "The Physical Condition of Our Forests and the Succeeding Tasks," (translated by the Hungarian Academy of Sciences, 1985), pp. 11–14.
35. Dr. Robert Bruck, 1985 (personal communication); and *op. cit.* 30, p. 6.
36. *Op. cit.* 1.
37. *Ibid.*
38. *Ibid.*
39. *Ibid.*
40. *Ibid.*
41. *Ibid.*
42. *Ibid.*
43. *Ibid.*
44. *Ibid.*
45. *Ibid.*
46. *Ibid.* Note: The 16 elements considered essential for all plant growth include: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, manganese, iron, copper, zinc, molybdenum, boron, and chlorine.
47. *Ibid.*
48. Sandra Postel, "Protecting Forests from Air Pollution and Acid Rain," *State of the World—1985* (Norton, New York, 1985), p. 103.
49. L. Skaby and G. Sellden, "The Effects of Ozone on Crops and Forests," *AMBIO*, Vol. 13, p. 69 (1984).
50. *Ibid.*
51. M. Ashmore, N. Bell, and J. Rutter, "The Role of Ozone in Forest Damage in West Germany," *AMBIO*, Vol. 14, pp. 82–83 (1985).
52. *Ibid.* p. 83.
53. *Op. cit.* 21, pp. 25–26
54. *Ibid.* p. 27.
55. *Ibid.* p. 30.
56. *Op. cit.* 21, p. 30.
57. *Op. cit.* 34; and Dr. R. Solymos, 1985 (personal communication).
58. N.H. Highton and M.J. Chadwick, "The Effects of Changing Patterns of Energy Use on Sulfur Emissions and Depositions in Europe," *AMBIO*, Vol. 11, pp. 326–327 (1982).
59. *Op. cit.* 21, pp. 33–34.
60. *Op. cit.* 16, p. 302.
61. P. Schütt, 1985 (personal communication).
62. *Op. cit.* 21, p. 34.
63. *Ibid.*
64. West German Federal Ministry for Research and Technology, Bonn, West Germany, 1985.
65. *Op. cit.* 21, p. 35.
66. B. Nihlgård, "The Ammonium Hypothesis—An Additional Explanation to the Forest Dieback in Europe," *AMBIO*, Vol. 14, p. 4 (1985).
67. *Ibid.*
68. *Ibid.* p. 5.
69. *Ibid.*
70. *Op. cit.* 21, p. 37.
71. *Ibid.* pp. 35–42.
72. *Ibid.*
73. *Ibid.* p. 41.
74. *Ibid.*
75. *Op. cit.* 66, p. 2.
76. Dr. Fritz Führ, 1985 (personal communication).
77. Dr. Peter Schütt, 1985 (personal communication).
78. *Op. cit.* 21, p. 44.
79. *Ibid.* p. 23.
80. P. Schütt, 1985 (personal communication).
81. *Op. cit.* 21, p. 22.
82. *Ibid.* p. 23.
83. B. Ulrich *et al.*, "Chemical Changes Due to Acid Precipitation on Soil," in *Beyond the Energy Crisis*, Fazzolare and Smith, Eds. (Pergamon Press, New York, 1981) pp. 555–564.
84. E. Matzner and B. Ulrich, "Effects of Acid Precipitation on Soil," in *Beyond the Energy Crisis*, Fazzolare and Smith, Eds. (Pergamon Press, New York, 1981) pp. 555–564.
85. *Ibid.*
86. *Op. cit.* 21, p. 54.
87. B. Ulrich, 1982 (personal communication).
88. R. Bruck, "Boreal Montane Ecosystem Decline in the Southern Appalachian Mountains: Potential Role of Anthropogenic Pollution," in *Air Pollutants Effects on Forest Ecosystems* (Acid Rain Foundation, St. Paul, Minnesota May 8–9, 1985), p. 150.
89. A. Friedland, *et al.*, "Trace Metal Content of the Forest Floor in the Green Mountains of Vermont: Spatial and Temporal Patterns," *Journal of Water, Air and Soil Pollution*, Vol. 26, pp. 161–170 (1984).
90. Andrew Friedland, 1985 (personal communication).
91. *Op. cit.* 21, p. 58.
92. D.R. Jackson, *et al.*, "Behavior of Heavy Metal in Forest Microcosms: Transport and Distribution Among Components," *Journal of Water, Air and Soil Pollution*, Vol. 10, pp. 3–11 (1978).
93. *Op. cit.* 21, p. 59.
94. *Op. cit.* 64.
95. Dr. Fritz Führ, 1985 (personal communication).
96. *Op. cit.* 64; and GSF, *Den Wald ins Laborholen* (Gesellschaft fur Strahlen und Umweltforschung Munchen, 1985), pp. 21–45.
97. Federal Ministry for Research and Technology, *Research on Environmental Damage to Forests*, (Federal Ministry for Research and Technology, Bonn, West Germany, 1984) pp. 14–15.
98. *Ibid.*
99. Dr. Bernhard Rami, 1985 (personal communication).
100. Charles Philpot, 1985 (personal communication).
101. EPA, Forest Service, *Forest Effects* (unpublished, 1985), p. 5.
102. *Op. cit.* 21, p. 62.
103. Charles Philpot, 1985 (personal communication).
104. *Op. cit.* 2, p. 8.
105. OTA, *Acid Rain and Transported Air Pollutants: Implications for Public Policy* (UNIPUB, New York, 1985), p. 149; and *op. cit.* 48, p. 113.
106. *Op. cit.* 48, p. 113.
107. *Op. cit.* 2, p. 6.
108. ECE, *Progress in Selected Areas of Cooperation* (U.N. Economic Commission for Europe, Executive Body for the Convention on Long-Range Transboundary Air Pollution, document E.B. AIR/R.12, 1985), p. 2.
109. *Op. cit.* 2, p. 7.
110. *Ibid.*
111. J. McCormick, *Acid Earth* (Earthscan, London, 1985), p. 67.
112. *Ibid.* p. 66.
113. *Ibid.*
114. Sarah Tooze, "West Germany Takes the Lead", *Nature*, Vol. 307, p. 309 (January 26, 1984).
115. Commission of the European Community, Council Directive, Brussels, Decem-

ber, 1983.

116. Robert McDonald, "EEC Auto Emissions Deal Could Still Unravel," *World Environment Report* p. 106 (July 10, 1985).
117. West German Federal Ministry for Research and Technology, Bonn, West Germany, 1985; and Dr. Reiner Kramer, 1985 (personal communication).
118. *Ibid.*
119. R. Spilker, "Controversy Continues over Buschhaus Plant," *AMBIO*, Vol. 13, Nos. 5–6, pp. 382–383 (1984).
120. Environment Canada Communication, Ottawa, Canada, 1985.
121. E. Cowling, *Pollution in the Air and Acids in the Rain: An Analysis of Present Knowledge and Certain Research Needs in the Southern United States* (Environment Conference, Tennessee Valley Authority, Knoxville, Tennessee, 1985), pp. 136–140.
122. *Op. cit.* 21, p. 68.
123. *Ibid.*
124. OTA, *Acid Rain and Transported Air Pollutants: Implications for Public Policy* (UNIPUB, New York, 1985) p. 157.
125. *Ibid.* p. 161.
126. *Ibid.* p. 163.
127. *Ibid.* p. 164.
128. *Ibid.* pp. 163–164.
129. ECE, *Draft Report on Technologies for Controlling NO Emissions from Mobile Sources* (Executive Body for the Convention on Long Range Transboundary Air Pollution, Document No. EB.AIR/R.17, April 11, 1985), pp. 1–15.
130. *Op. cit.* 124, p. 14.

# 1. Basic Economic Indicators

Employment, production, and price statistics are three basic economic indicators that are used in most countries to monitor levels of, and short-term changes in economic activity.

Gross National Product (GNP), perhaps the most important indicator of economic growth, measures the total market value of goods and services produced in a country in a year, taking into account trade with other countries. There are two major problems with using GNP as a broader measure of economic development: the first is comparability among countries; the second is the extent to which economically valuable activities and resources are covered.

The GNP figures used here have been taken from World Bank data files and publications. They are usually more accurate for countries in which economic transactions (trade in goods, services, and labor) go through a marketplace and can be accurately recorded. Data for many developing countries, where markets are not as well developed or where data collection systems are rudimentary, require extensive imputations. In all countries a fraction of economic activity occurs in black markets and its value is not adequately represented in official statistics. Countries at war or suffering civil strife, such as Lebanon, Democratic Kampuchea, Afghanistan, Iran, and Iraq, do not report GNP data, or the figures they have are incomplete. GNP data for non-market economies such as the Soviet Union, Viet Nam, and Cuba are very difficult to calculate and interpret, and, except for Hungary, are omitted from Table 1.1.

Comparing the GNP of one country to another requires the use of a common currency (most often, U.S. dollars) and a common base year. However, currency exchange rates do not accurately reflect the relative purchasing powers of currencies. For example, the price of labor services (such as haircuts) relative to those of commodities that enter international trade (such as wheat) differs systematically between high- and low-income countries. GNP estimates converted to dollars using currency exchange rates substantially overstate international differences in real living standards. The procedures used by the World Bank to calculate GNP in constant U.S. dollars are described in the *World Development Report 1985.* Updated GNP figures are available in the latest issue of the *World Bank Atlas.*

The problem of coverage is more difficult to overcome. GNP tells us little about a nation's wealth in human and natural resources, and changes in a nation's natural resource assets are not adequately accounted for. Rapid depletion of ground-water, fisheries, forests, soils, and other natural resources reduce a nation's potential future income. The current economic gain from the water used, the fish caught, the wood sold, and the crops grown is treated as a positive contribution to GNP, but the depletion of the value of the natural resource asset is not subtracted. Using current GNP figures as indicators of long-term economic opportunities, therefore, can be very misleading.

The size of the labor force, presented in Table 1.2, is an important measure of employment opportunity in a country. The total labor force is composed of all persons who work to produce economic goods and services, including the unemployed. Current estimates are based on information available to the International Labor Organization (ILO) in the mid-1970s. Because of severe economic recessions and substantial migration of workers across international borders, the figures for some countries may no longer be reliable.

World commodity prices presented in Table 1.3 (also from World Bank sources) are for commodities that are traded in world markets. These same materials are traded locally within countries at prices that may vary widely from those of global markets because of transportation costs, tariffs, trade restrictions, and other factors. Many important commodities, such as wild plants and animals, are traded less frequently and sometimes illegally. Data for these commodities are not included here.

The data on international commodity price trends reflect market prices converted to U.S. dollars and deflated for inflation. The World Bank uses the Manufacturing Unit Value (MUV) Index as a deflator because it reflects changes in the price of goods that developing countries buy on the world market. The price trend for 33 non-fuel commodities, for example, has been one of sharp decline. Using the MUV deflator, the combined price index of these commodities stood at 160 in 1970, at 100 in 1977–79, and at 84 in 1984. This represents a halving of the purchasing power of raw materials in terms of manufactured goods.

# Table 1.1 GROSS NATIONAL PRODUCT, 1960–83

| | Gross National Product 1983 | | Average Annual Growth Rate of Real GNP (percent) | | Distribution of Gross Domestic Product 1983 (percent) | | |
|---|---|---|---|---|---|---|---|
| | Total (millions of $US) | Per Capita ($US) | 1960–75 | 1975–83 | Agriculture | Industry | Services |
| **WORLD** | | | | | | | |
| **AFRICA** | | | | | | | |
| Algeria | 49450 | 2400 | 5.8 | 6.0 | 6 | 54 | 40 |
| Angola | X | X | 2.8 | 0.3 | X | X | X |
| Benin | 1110 | 290 | 2.9 | 5.3 | 40 | 14 | 47 |
| Botswana | 920 | 920 | 10.1 | 11.7 | X | X | X |
| Burkina Faso | 1210 | 180 | 2.8 | 3.3 | 41 | 19 | 40 |
| Burundi | 1050 | 240 | 4.0 | 3.9 | 58 | 16 | 26 |
| Cameroon | 7640 | 800 | 4.2 | 7.3 | 24 | 32 | 45 |
| Cape Verde | 110 | 360 | X | 7.5 | X | X | X |
| Central African Rep | 690 | 280 | 2.3 | -0.2 | 37 | 21 | 42 |
| Chad | X | X | 0.7 | -9.5 | X | X | X |
| Comoros | X | X | 5.1 | 6.0 | X | X | X |
| Congo | 2180 | 1230 | 5.2 | 9.6 | 7 | 55 | 38 |
| Djibouti | X | X | X | 1.8 | X | X | X |
| Egypt | 31880 | 700 | 4.5 | 8.6 | 20 | 33 | 47 |
| Equatorial Guinea | X | X | 0.7 | X | X | X | X |
| Ethiopia | 4860 | 140 | 4.3 | 3.1 | 48 | 16 | 36 |
| Gabon | 2950 | 4250 | 7.3 | -7.4 | X | X | X |
| Gambia | 200 | 290 | 6.1 | 1.5 | X | X | X |
| Ghana | 3980 | 320 | 2.4 | -1.1 | 53 | 7 | 40 |
| Guinea | 1740 | 300 | 3.3 | 1.5 | 38 | 23 | 39 |
| Guinea-Bissau | 150 | 180 | X | 1.8 | X | X | X |
| Ivory Coast | 6730 | 720 | 7.3 | 3.4 | 27 | 24 | 50 |
| Kenya | 6450 | 340 | 7.1 | 5.0 | 33 | 20 | 46 |
| Lesotho | 670 | 470 | 8.6 | 4.2 | 23 | 22 | 55 |
| Liberia | 990 | 470 | 4.9 | 1.5 | 36 | 26 | 38 |
| Libya | 25100 | 7500 | 12.5 | 2.0 | 2 | 64 | 34 |
| Madagascar | 2730 | 290 | 2.8 | -0.3 | 41 | 15 | 44 |
| Malawi | 1390 | 210 | 6.0 | 3.7 | X | X | X |
| Mali | 1110 | 150 | 3.1 | 3.1 | 46 | 11 | 43 |
| Mauritania | 720 | 440 | 4.8 | 2.9 | 34 | 21 | 45 |
| Mauritius | 1250 | 1150 | 2.8 | 2.7 | X | X | X |
| Morocco | 15620 | 750 | 4.9 | 3.5 | 17 | 32 | 51 |
| Mozambique | X | X | 4.5 | 0.1 | X | X | X |
| Niger | 1460 | 240 | 0.7 | 5.5 | 33 | 31 | 37 |
| Nigeria | 71030 | 760 | 6.4 | -0.3 | 26 | 34 | 40 |
| Rwanda | 1540 | 270 | 4.1 | 5.1 | X | X | X |
| Senegal | 2730 | 440 | 2.1 | 1.8 | 21 | 26 | 54 |
| Sierra Leone | 1230 | 380 | 4.1 | 1.8 | 32 | 20 | 48 |
| Somalia | 1140 | 250 | 1.7 | 1.2 | 50 | 11 | 39 |
| South Africa | 76890 | 2450 | 5.6 | 2.9 | X | X | X |
| Sudan | 8420 | 400 | 1.2 | 3.3 | 34 | 15 | 51 |
| Swaziland | 610 | 890 | 9.2 | 2.5 | X | X | X |
| Tanzania, United Rep | 4880 | 240 | 5.7 | 1.8 | 52 | 15 | 33 |
| Togo | 790 | 280 | 6.8 | 1.8 | 22 | 28 | 50 |
| Tunisia | 8860 | 1290 | 6.3 | 5.5 | 14 | 36 | 50 |
| Uganda | 3090 | 220 | 4.3 | -2.0 | X | X | X |
| Zaire | 5050 | 160 | 4.0 | 0.0 | 36 | 20 | 44 |
| Zambia | 3630 | 580 | 4.5 | 0.4 | 14 | 38 | 48 |
| Zimbabwe | 5820 | 740 | 5.8 | 4.6 | 11 | 32 | 57 |
| **NORTH AMERICA** | | | | | | | |
| Barbados | 1020 | 3930 | 6.0 | 2.7 | X | X | X |
| Canada | 300400 | 12000 | 5.4 | 1.7 | 3 | 29 | 68 |
| Costa Rica | 2420 | 1020 | 6.6 | 1.0 | 23 | 27 | 50 |
| Cuba | X | X | X | X | X | X | X |
| Dominican Rep | 8170 | 1380 | 6.4 | 3.9 | 17 | 29 | 55 |
| El Salvador | 3690 | 710 | 5.3 | -2.2 | 20 | 21 | 59 |
| Guatemala | 8890 | 1120 | 5.7 | 3.0 | X | X | X |
| Haiti | 1700 | 320 | 1.3 | 2.9 | X | X | X |
| Honduras | 2740 | 670 | 4.4 | 4.1 | 27 | 26 | 47 |
| Jamaica | 2940 | 1300 | 4.5 | -1.9 | 7 | 34 | 60 |
| Mexico | 168070 | 2240 | 7.5 | 5.1 | 8 | 40 | 52 |
| Nicaragua | 2690 | 900 | 5.7 | -2.7 | 22 | 32 | 47 |
| Panama | 4070 | 2070 | 7.2 | 5.5 | X | X | X |
| Trinidad and Tobago | 7870 | 6900 | 3.5 | 4.5 | X | X | X |
| United States | 3292340 | 14090 | 3.7 | 2.4 | 2 | 32 | 66 |
| **SOUTH AMERICA** | | | | | | | |
| Argentina | 58560 | 2030 | 4.2 | -0.8 | 12 | 39 | 49 |
| Bolivia | 3070 | 510 | 4.8 | -1.4 | 23 | 26 | 52 |
| Brazil | 245590 | 1890 | 7.5 | 3.4 | 12 | 35 | 53 |
| Chile | 21890 | 1870 | 3.0 | 3.4 | 10 | 36 | 55 |
| Colombia | 38830 | 1410 | 5.6 | 4.0 | 20 | 28 | 51 |
| Ecuador | 11690 | 1430 | 8.2 | 4.0 | 14 | 40 | 46 |
| Guyana | 410 | 520 | 4.6 | -2.9 | X | X | X |
| Paraguay | 4540 | 1410 | 4.8 | 8.3 | 26 | 26 | 48 |
| Peru | 18650 | 1040 | 4.5 | 0.7 | 8 | 41 | 51 |
| Suriname | 1280 | 3520 | 7.0 | 3.0 | X | X | X |
| Uruguay | 7390 | 2490 | 1.8 | 1.8 | 12 | 28 | 60 |
| Venezuela | 70820 | 4100 | 6.1 | 0.7 | 7 | 40 | 53 |

# Table 1.1

| | Gross National Product 1983 | | Average Annual Growth Rate of Real GNP (percent) | | Distribution of Gross Domestic Product 1983 (percent) | | |
|---|---|---|---|---|---|---|---|
| | Total (millions of $US) | Per Capita ($US) | 1960–75 | 1975–83 | Agriculture | Industry | Services |
| **ASIA** | | | | | | | |
| Afghanistan | X | X | 2.0 | 1.5 | X | X | X |
| Bahrain | 4120 | 10360 | X | 6.4 | X | X | X |
| Bangladesh | 12530 | 130 | 1.9 | 4.9 | 47 | 13 | 40 |
| Bhutan | X | X | X | 4.0 | X | X | X |
| Burma | 6500 | 180 | 2.9 | 6.1 | 48 | 13 | 39 |
| China | 301840 | 290 | 7.1 | 7.1 | 37 | 45 | 18 |
| Cyprus | 2430 | 3720 | 7.0 | 7.3 | X | X | X |
| India | 190710 | 260 | 3.5 | 3.9 | 36 | 26 | 38 |
| Indonesia | 87120 | 560 | 5.7 | 6.8 | 26 | 39 | 35 |
| Iran | X | X | 11.3 | −1.7 | X | X | X |
| Iraq | X | X | 6.7 | 17.0 | X | X | X |
| Israel | 21990 | 5360 | 8.5 | 3.1 | 6 | 27 | 67 |
| Japan | 1204270 | 10100 | 9.2 | 4.6 | 4 | 42 | 55 |
| Jordan | 4400 | 1710 | X | 10.5 | 8 | 31 | 61 |
| Kampuchea, Dem | X | X | −0.2 | X | X | X | X |
| Korea, Dem People's Rep | X | X | X | X | X | X | X |
| Korea, Rep | 80310 | 2010 | 9.0 | 6.2 | 14 | 39 | 47 |
| Kuwait | 30290 | 18180 | 5.9 | 5.5 | 1 | 61 | 38 |
| Lao People's Dem Rep | X | X | X | X | X | X | X |
| Lebanon | X | X | 5.2 | X | X | X | X |
| Malaysia | 27760 | 1870 | 6.8 | 7.3 | 21 | 35 | 44 |
| Mongolia | X | X | X | X | X | X | X |
| Nepal | 2660 | 170 | 2.2 | 2.9 | 59 | 14 | 27 |
| Oman | 7070 | 6240 | 13.7 | 7.1 | X | X | X |
| Pakistan | 35000 | 390 | 6.2 | 6.6 | 27 | 27 | 46 |
| Philippines | 39420 | 760 | 5.4 | 4.9 | 22 | 36 | 42 |
| Qatar | 5960 | 21170 | X | −2.8 | X | X | X |
| Saudi Arabia | 127080 | 12180 | 11.9 | 6.7 | 2 | 66 | 32 |
| Singapore | 16560 | 6620 | 9.9 | 8.3 | 1 | 37 | 62 |
| Sri Lanka | 5140 | 330 | 4.3 | 5.2 | 27 | 26 | 47 |
| Syrian Arab Rep | 16510 | 1680 | 6.4 | 6.0 | 19 | 25 | 55 |
| Thailand | 40380 | 810 | 7.8 | 6.0 | 23 | 27 | 50 |
| Turkey | 58260 | 1230 | 6.6 | 2.5 | 19 | 33 | 48 |
| United Arab Emirates | 25770 | 21340 | X | 10.8 | 1 | 65 | 34 |
| Viet Nam | X | X | X | X | X | X | X |
| Yemen | 3930 | 510 | X | 7.4 | 21 | 17 | 62 |
| Yemen, Dem | 1020 | 510 | X | 7.4 | X | X | X |
| **EUROPE** | | | | | | | |
| Albania | X | X | X | X | X | X | X |
| Austria | 69830 | 9210 | 4.8 | 2.6 | 4 | 39 | 58 |
| Belgium | 90540 | 9160 | 4.8 | 1.4 | 2 | 35 | 63 |
| Bulgaria | X | X | X | X | X | X | X |
| Czechoslovakia | X | X | X | X | X | X | X |
| Denmark | 58850 | 11490 | 3.8 | 1.5 | 4 | 23 | 72 |
| Finland | 50730 | 10440 | 4.6 | 3.1 | 7 | 33 | 60 |
| France | 568690 | 10390 | 5.3 | 2.3 | X | X | X |
| German Dem Rep | X | X | X | X | X | X | X |
| Germany, Fed Rep | 702440 | 11420 | 4.2 | 2.2 | 2 | 46 | 52 |
| Greece | 39210 | 3970 | 7.1 | 2.5 | 17 | 29 | 53 |
| Hungary | 23050 | 2150 | 6.2 | 2.8 | 19 | 42 | 39 |
| Ireland | 16960 | 4810 | 4.3 | 1.8 | X | X | X |
| Italy | 357570 | 6350 | 4.9 | 2.3 | 6 | 40 | 54 |
| Luxembourg | 4470 | 12190 | 5.0 | 3.8 | X | X | X |
| Malta | 1310 | 3710 | 6.6 | 7.7 | X | X | X |
| Netherlands | 142420 | 9910 | 4.9 | 1.2 | 4 | 33 | 63 |
| Norway | 57090 | 13820 | 4.2 | 3.0 | 4 | 42 | 55 |
| Poland | X | X | X | X | X | X | X |
| Portugal | 22490 | 2190 | 6.4 | 3.1 | 8 | 40 | 51 |
| Romania | X | X | X | 5.2 | X | X | X |
| Spain | 182760 | 4800 | 6.6 | 1.4 | X | X | X |
| Sweden | 103240 | 12400 | 3.9 | 0.8 | 3 | 31 | 66 |
| Switzerland | 105060 | 16390 | 3.9 | 1.7 | X | X | X |
| United Kingdom | 505610 | 9050 | 2.8 | 1.2 | 2 | 32 | 66 |
| Yugoslavia | 58520 | 2570 | 6.1 | 3.7 | X | X | X |
| **USSR** | X | X | X | X | X | X | X |
| **OCEANIA** | | | | | | | |
| Australia | 166230 | 10780 | 5.2 | 2.3 | X | X | X |
| Fiji | 1190 | 1790 | 6.0 | 3.1 | X | X | X |
| New Zealand | 24000 | 7410 | 3.9 | 0.4 | 8 | 33 | 59 |
| Papua New Guinea | 2510 | 790 | 6.0 | 1.2 | X | X | X |
| Solomon Islands | 160 | 640 | X | 4.8 | X | X | X |
| **ANTARCTICA** | | | | | | | |

**Source:** The World Bank.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 1.2 LABOR FORCE, 1965–2000

| | Total Labor Force 1983 (thousands) | Percentage of Labor Force in: Agriculture 1965 | Agriculture 1981 | Industry 1965 | Industry 1981 | Services 1965 | Services 1981 | Average Annual Growth of the Labor Force (percent) 1965–73 | 1973–83 | 1980–2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **WORLD** | | | | | | | | | | |
| **AFRICA** | | | | | | | | | | |
| Algeria | 4670 | 59 | 25 | 14 | 25 | 27 | 50 | 1.6 | 3.6 | 4.5 |
| Angola | 1986 | 67 | 59 | 13 | 16 | 20 | 25 | 1.7 | 2.8 | 2.8 |
| Benin | 1751 | 52 | 46 | 10 | 16 | 38 | 38 | 2.1 | 2.0 | 2.7 |
| Botswana | 405 | X | X | X | X | X | X | X | X | X |
| Burkina Faso | 3927 | 90 | 82 | 6 | 13 | 4 | 5 | 1.6 | 1.5 | 2.1 |
| Burundi | 2141 | 89 | 84 | 4 | 5 | 7 | 11 | 1.2 | 1.6 | 2.5 |
| Cameroon | 4112 | 86 | 83 | 6 | 7 | 8 | 10 | 1.9 | 1.8 | 3.2 |
| Cape Verde | 109 | X | X | X | X | X | X | X | X | X |
| Central African Rep | 1307 | 93 | 88 | 3 | 4 | 4 | 8 | 1.1 | 1.6 | 2.4 |
| Chad | 1805 | 93 | 85 | 3 | 7 | 4 | 8 | 1.6 | 2.3 | 2.3 |
| Comoros | 140 | X | X | X | X | X | X | X | X | X |
| Congo | 563 | 47 | 34 | 19 | 26 | 34 | 40 | 1.9 | 1.8 | 3.8 |
| Djibouti | X | X | X | X | X | X | X | X | X | X |
| Egypt | 12753 | 56 | 50 | 15 | 30 | 29 | 20 | 2.2 | 2.4 | 2.3 |
| Equatorial Guinea | 114 | X | X | X | X | X | X | X | X | X |
| Ethiopia | 13676 | 86 | 80 | 6 | 7 | 8 | 13 | 2.2 | 1.4 | 2.2 |
| Gabon | 268 | X | X | X | X | X | X | X | X | X |
| Gambia | 312 | X | X | X | X | X | X | X | X | X |
| Ghana | 4719 | 61 | 53 | 16 | 20 | 23 | 27 | 1.6 | 2.0 | 3.8 |
| Guinea | 2376 | 87 | 82 | 7 | 11 | 6 | 7 | 1.2 | 1.3 | 2.4 |
| Guinea-Bissau | 182 | X | X | X | X | X | X | X | X | X |
| Ivory Coast | 4338 | 87 | 79 | 3 | 4 | 10 | 17 | 4.2 | 3.8 | 3.3 |
| Kenya | 6903 | 84 | 78 | 6 | 10 | 10 | 12 | 3.2 | 2.9 | 4.0 |
| Lesotho | 743 | 92 | 60 | 3 | 15 | 5 | 25 | 1.7 | 1.9 | 2.5 |
| Liberia | 785 | 78 | 70 | 11 | 14 | 11 | 16 | 2.0 | 3.9 | 2.8 |
| Libya | 832 | 42 | 19 | 20 | 28 | 38 | 53 | 3.6 | 4.3 | 4.3 |
| Madagascar | 4544 | 92 | 87 | 3 | 4 | 5 | 9 | 1.9 | 1.7 | 3.0 |
| Malawi | 2992 | 91 | 86 | 4 | 5 | 5 | 9 | 2.4 | 2.8 | 2.8 |
| Mali | 3999 | 93 | 73 | 4 | 12 | 3 | 15 | 2.2 | 2.0 | 2.6 |
| Mauritania | 538 | 90 | 69 | 4 | 8 | 6 | 23 | 1.9 | 2.4 | 2.0 |
| Mauritius | 374 | X | X | X | X | X | X | X | X | X |
| Morocco | 5938 | 60 | 52 | 15 | 21 | 25 | 27 | 1.6 | 2.8 | 3.1 |
| Mozambique | 4173 | 77 | 66 | 10 | 18 | 13 | 16 | 2.2 | 3.0 | 2.9 |
| Niger | 1794 | 94 | 91 | 1 | 3 | 5 | 6 | 2.4 | 3.0 | 3.1 |
| Nigeria | 31436 | 67 | 54 | 12 | 19 | 21 | 27 | 1.8 | 2.0 | 3.3 |
| Rwanda | 2718 | 94 | 91 | 1 | 2 | 5 | 7 | 2.7 | 3.0 | 3.2 |
| Senegal | 2491 | 82 | 77 | 6 | 10 | 12 | 13 | 1.7 | 2.2 | 2.6 |
| Sierra Leone | 1383 | 75 | 65 | 14 | 19 | 11 | 16 | 0.7 | 1.2 | 1.7 |
| Somalia | 1994 | 87 | 82 | 5 | 8 | 8 | 10 | 3.8 | 2.0 | 1.7 |
| South Africa | 11433 | 32 | 30 | 30 | 29 | 38 | 41 | 2.7 | 3.2 | 2.9 |
| Sudan | 6158 | 84 | 78 | 7 | 10 | 9 | 12 | 2.5 | 2.5 | 2.9 |
| Swaziland | 273 | X | X | X | X | X | X | X | X | X |
| Tanzania, United Rep | 7909 | 88 | 83 | 4 | 6 | 8 | 11 | 2.5 | 2.5 | 3.1 |
| Togo | 1159 | 81 | 67 | 10 | 15 | 9 | 18 | 2.2 | 1.9 | 2.9 |
| Tunisia | 1646 | 53 | 35 | 20 | 32 | 27 | 33 | 1.4 | 2.9 | 2.9 |
| Uganda | 5860 | 88 | 83 | 5 | 6 | 7 | 11 | 3.0 | 1.7 | 3.4 |
| Zaire | 12717 | 81 | 75 | 10 | 13 | 9 | 12 | 1.8 | 2.2 | 3.0 |
| Zambia | 2263 | 76 | 67 | 8 | 11 | 16 | 22 | 2.3 | 2.1 | 3.3 |
| Zimbabwe | 2641 | 67 | 60 | 12 | 15 | 21 | 25 | 2.7 | 1.4 | 4.4 |
| **NORTH AMERICA** | | | | | | | | | | |
| Barbados | 118 | X | X | X | X | X | X | X | X | X |
| Canada | 10695 | 11 | 5 | 33 | 29 | 56 | 66 | 2.7 | 2.0 | 1.1 |
| Costa Rica | 809 | 47 | 29 | 20 | 23 | 33 | 48 | 3.6 | 3.6 | 2.8 |
| Cuba | 3079 | 35 | 23 | 24 | 31 | 41 | 46 | 1.0 | 2.1 | 1.7 |
| Dominican Rep | 1681 | 64 | 49 | 13 | 18 | 23 | 33 | 2.7 | 3.2 | 2.8 |
| El Salvador | 1637 | 59 | 50 | 18 | 22 | 23 | 28 | 3.2 | 2.8 | 3.4 |
| Guatemala | 2407 | 64 | 55 | 16 | 21 | 20 | 24 | 2.9 | 3.0 | 2.9 |
| Haiti | 3091 | 77 | 74 | 7 | 7 | 16 | 19 | 0.7 | 1.5 | 2.0 |
| Honduras | 1206 | 68 | 63 | 12 | 20 | 20 | 17 | 2.4 | 3.3 | 3.5 |
| Jamaica | 824 | 34 | 35 | 25 | 18 | 41 | 47 | 0.7 | 2.6 | 2.6 |
| Mexico | 21961 | 50 | 36 | 21 | 26 | 29 | 38 | 3.1 | 3.1 | 3.2 |
| Nicaragua | 898 | 57 | 39 | 16 | 14 | 27 | 47 | 2.8 | 4.0 | 3.8 |
| Panama | 692 | 46 | 33 | 15 | 18 | 39 | 49 | 3.1 | 2.6 | 2.4 |
| Trinidad and Tobago | 481 | 23 | 10 | 35 | 39 | 42 | 51 | 1.8 | 1.2 | 2.3 |
| United States | 107136 | 5 | 2 | 36 | 32 | 59 | 66 | 1.9 | 1.7 | 0.9 |
| **SOUTH AMERICA** | | | | | | | | | | |
| Argentina | 10691 | 18 | 13 | 34 | 28 | 48 | 59 | 1.4 | 1.0 | 1.4 |
| Bolivia | 1966 | 58 | 50 | 20 | 24 | 22 | 26 | 1.8 | 2.5 | 2.8 |
| Brazil | 41406 | 49 | 30 | 17 | 24 | 34 | 46 | 2.5 | 3.1 | 2.4 |
| Chile | 3938 | 26 | 19 | 21 | 19 | 53 | 62 | 1.3 | 2.6 | 2.0 |
| Colombia | 8297 | 45 | 26 | 20 | 21 | 35 | 53 | 3.1 | 2.8 | 2.6 |
| Ecuador | 2830 | 54 | 52 | 21 | 17 | 25 | 31 | 2.6 | 2.6 | 3.3 |
| Guyana | 318 | X | X | X | X | X | X | X | X | X |
| Paraguay | 1124 | 55 | 49 | 19 | 19 | 26 | 32 | 2.6 | 3.3 | 3.0 |
| Peru | 5705 | 50 | 40 | 19 | 19 | 31 | 41 | 2.4 | 2.9 | 3.0 |
| Suriname | 108 | X | X | X | X | X | X | X | X | X |
| Uruguay | 1159 | 18 | 11 | 30 | 32 | 52 | 57 | 0.3 | 0.5 | 0.9 |
| Venezuela | 5369 | 30 | 18 | 24 | 27 | 46 | 55 | 3.7 | 4.1 | 3.4 |

# Table 1.2

| | Total Labor Force 1983 (000) | Percentage of Labor Force in: Agriculture 1965 | Agriculture 1981 | Industry 1965 | Industry 1981 | Services 1965 | Services 1981 | Average Annual Growth of the Labor Force (percent) 1965–73 | 1973–83 | 1980–2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| **ASIA** | | | | | | | | | | |
| Afghanistan | 5715 | 84 | 79 | 7 | 8 | 9 | 13 | 1.9 | 2.3 | 2.4 |
| Bahrain | X | X | X | X | X | X | X | X | X | X |
| Bangladesh | 32382 | 87 | 74 | 3 | 11 | 10 | 15 | 2.3 | 2.8 | 2.9 |
| Bhutan | 664 | 95 | 93 | 2 | 2 | 3 | 5 | 1.0 | 1.9 | 2.1 |
| Burma | 14936 | X | 67 | X | 10 | X | 23 | 1.3 | 1.4 | 2.2 |
| China | 480379 | X | 74 | X | 13 | X | 13 | 2.4 | 1.2 | 1.8 |
| Cyprus | 279 | X | X | X | X | X | X | X | X | X |
| India | 275894 | 74 | 71 | 11 | 13 | 15 | 16 | 1.8 | 2.1 | 2.1 |
| Indonesia | 52963 | 71 | 58 | 9 | 12 | 20 | 30 | 1.9 | 2.3 | 2.4 |
| Iran | 11560 | 50 | 39 | 26 | 34 | 24 | 27 | 3.1 | 3.0 | 3.5 |
| Iraq | 3529 | 50 | 42 | 20 | 26 | 30 | 32 | 2.9 | 3.1 | 3.7 |
| Israel | 1469 | 12 | 7 | 35 | 36 | 53 | 57 | 3.2 | 2.3 | 2.2 |
| Japan | 61604 | 26 | 12 | 32 | 39 | 42 | 49 | 1.7 | 1.1 | 0.7 |
| Jordan | 858 | 41 | 20 | 16 | 20 | 43 | 60 | 2.6 | 1.4 | 4.6 |
| Kampuchea, Dem | 2722 | 80 | X | 4 | X | 16 | X | 1.3 | X | X |
| Korea, Dem People's Rep | 8695 | 59 | 49 | 25 | 33 | 16 | 18 | 2.6 | 2.9 | 2.7 |
| Korea, Rep | 15732 | 58 | 34 | 13 | 29 | 29 | 37 | 2.9 | 2.7 | 1.9 |
| Kuwait | 401 | 1 | 2 | 34 | 34 | 65 | 64 | 5.3 | 7.1 | 3.2 |
| Lao People's Dem Rep | 1863 | 81 | 75 | 5 | 6 | 14 | 19 | 0.6 | 0.9 | 2.5 |
| Lebanon | 729 | 28 | 11 | 25 | 27 | 47 | 62 | 2.5 | −0.1 | 2.1 |
| Malaysia | 5178 | 60 | 50 | 13 | 16 | 27 | 34 | 2.9 | 3.2 | 2.7 |
| Mongolia | 676 | 66 | 55 | 15 | 22 | 19 | 23 | 2.2 | 2.6 | 2.9 |
| Nepal | 7177 | 95 | 93 | 2 | 2 | 3 | 5 | 1.6 | 2.3 | 2.5 |
| Oman | X | X | X | X | X | X | X | X | X | X |
| Pakistan | 25375 | 60 | 57 | 19 | 20 | 21 | 23 | 2.3 | 3.2 | 2.7 |
| Philippines | 18314 | 57 | 46 | 16 | 17 | 27 | 37 | 2.1 | 3.0 | 2.5 |
| Qatar | X | X | X | X | X | X | X | X | X | X |
| Saudi Arabia | 2561 | 69 | 61 | 11 | 14 | 20 | 25 | 3.9 | 5.8 | 3.2 |
| Singapore | 1000 | 6 | 2 | 26 | 39 | 68 | 59 | 3.4 | 2.3 | 1.1 |
| Sri Lanka | 5594 | 56 | 54 | 14 | 14 | 30 | 32 | 2.0 | 2.1 | 2.2 |
| Syrian Arab Rep | X | 53 | 33 | 20 | 31 | 27 | 36 | 3.1 | 3.5 | 4.0 |
| Thailand | 22357 | 82 | 76 | 5 | 9 | 13 | 15 | 2.4 | 3.1 | 2.1 |
| Turkey | 19942 | 74 | 54 | 11 | 13 | 15 | 33 | 1.8 | 2.0 | 2.1 |
| United Arab Emirates | X | X | X | X | X | X | X | X | X | X |
| Viet Nam | 25782 | 79 | 71 | 6 | 10 | 15 | 19 | X | X | 2.9 |
| Yemen | 1701 | 81 | 75 | 8 | 11 | 11 | 14 | 1.0 | 2.1 | 3.3 |
| Yemen, Dem | 512 | 68 | 45 | 16 | 15 | 16 | 40 | 1.1 | 1.8 | 3.3 |
| **EUROPE** | | | | | | | | | | |
| Albania | 1257 | 69 | 61 | 19 | 25 | 12 | 14 | 2.4 | 2.6 | 2.4 |
| Austria | 3430 | 19 | 9 | 45 | 37 | 36 | 54 | −0.2 | 0.9 | 0.3 |
| Belgium | 4007 | 6 | 3 | 46 | 41 | 48 | 56 | 0.5 | 0.7 | 0.2 |
| Bulgaria | 4687 | 52 | 37 | 28 | 39 | 20 | 24 | 0.6 | 0.1 | 0.2 |
| Czechoslovakia | 7699 | 21 | 11 | 48 | 48 | 31 | 41 | 0.8 | 0.6 | 0.6 |
| Denmark | 2482 | 14 | 7 | 37 | 35 | 49 | 58 | 0.8 | 0.6 | 0.4 |
| Finland | 2412 | 28 | 11 | 33 | 35 | 39 | 54 | 0.5 | 0.4 | 0.4 |
| France | 23628 | 18 | 8 | 40 | 39 | 42 | 53 | 0.7 | 1.0 | 0.6 |
| German Dem Rep | 8922 | 15 | 10 | 49 | 50 | 36 | 40 | 0.4 | 0.8 | 0.3 |
| Germany, Fed Rep | 29525 | 10 | 4 | 48 | 46 | 42 | 50 | 0.3 | 0.8 | −0.1 |
| Greece | 4138 | 51 | 37 | 22 | 28 | 27 | 35 | 0.1 | 0.9 | 0.5 |
| Hungary | 5207 | 32 | 21 | 39 | 43 | 29 | 36 | 0.5 | X | 0.1 |
| Ireland | 1304 | 31 | 18 | 28 | 37 | 41 | 45 | 0.5 | 1.5 | 1.5 |
| Italy | 21685 | 24 | 11 | 42 | 45 | 34 | 44 | 0.0 | 0.6 | 0.2 |
| Luxembourg | X | X | X | X | X | X | X | X | X | X |
| Malta | 122 | X | X | X | X | X | X | X | X | X |
| Netherlands | 5606 | 9 | 6 | 43 | 45 | 48 | 49 | 1.4 | 1.4 | 0.5 |
| Norway | 1568 | 15 | 7 | 37 | 37 | 48 | 56 | 0.6 | 0.7 | 0.6 |
| Poland | 20396 | 44 | 31 | 32 | 39 | 24 | 30 | 1.7 | 1.2 | 0.8 |
| Portugal | 3892 | 39 | 28 | 31 | 35 | 30 | 37 | 0.1 | 0.9 | 0.6 |
| Romania | 12372 | 58 | 29 | 19 | 36 | 23 | 35 | 0.8 | 0.5 | 0.7 |
| Spain | 13428 | 34 | 14 | 35 | 40 | 31 | 46 | 0.4 | 1.2 | 0.8 |
| Sweden | 3664 | 11 | 5 | 43 | 34 | 46 | 61 | 0.7 | 0.4 | 0.4 |
| Switzerland | 3248 | 10 | 5 | 50 | 46 | 40 | 49 | 1.5 | 0.4 | 0.1 |
| United Kingdom | 26241 | 3 | 2 | 46 | 42 | 51 | 56 | 0.2 | 0.4 | 0.2 |
| Yugoslavia | 10493 | 57 | 29 | 21 | 35 | 22 | 36 | 0.7 | 0.5 | 0.6 |
| **USSR** | 136140 | 33 | 14 | 33 | 45 | 34 | 41 | 0.8 | 1.1 | 0.6 |
| **OCEANIA** | | | | | | | | | | |
| Australia | 6376 | 10 | 6 | 38 | 33 | 52 | 61 | 2.5 | 1.6 | 1.2 |
| Fiji | 227 | X | X | X | X | X | X | X | X | X |
| New Zealand | 1289 | 13 | 10 | 36 | 35 | 51 | 55 | 2.0 | 1.2 | 1.0 |
| Papua New Guinea | 1670 | 88 | 82 | 5 | 8 | 7 | 10 | 1.9 | 1.4 | 2.2 |
| Solomon Islands | X | X | X | X | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | | | | | |

**Sources:** International Labor Organization; U.N. Food and Agriculture Organization.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 1.3 WORLD COMMODITY PRICES AND INDEXES, 1961-84

**COMMODITY INDEXES (Index Numbers Based on 1977-79 = 100)**

| | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| ALL FOODS | 93 | 94 | 130 | 117 | 92 | 87 | 86 | 91 | 100 | 99 |
| BEVERAGES | 70 | 68 | 67 | 75 | 71 | 66 | 63 | 67 | 68 | 72 |
| CEREALS | 128 | 143 | 143 | 138 | 135 | 144 | 150 | 156 | 153 | 126 |
| FATS AND OILS | 113 | 107 | 113 | 114 | 126 | 116 | 108 | 111 | 109 | 116 |
| OTHER FOODS | 103 | 107 | 241 | 179 | 90 | 81 | 83 | 89 | 122 | 122 |
| NON-FOOD AGRICULTURALS | 139 | 141 | 130 | 129 | 126 | 120 | 113 | 125 | 132 | 112 |
| TIMBER | 78 | 87 | 84 | 70 | 81 | 80 | 84 | 92 | 88 | 85 |
| METALS AND MINERALS | 129 | 127 | 124 | 149 | 170 | 173 | 143 | 156 | 169 | 160 |

**COMMODITY PRICES (Current Prices in $US; Constant Prices in 1980 $US)**

| | | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cocoa | current | 0.49 | 0.46 | 0.55 | 0.51 | 0.37 | 0.52 | 0.60 | 0.72 | 0.90 | 0.68 |
| (kg) | constant | 1.74 | 1.69 | 2.01 | 1.79 | 1.30 | 1.74 | 1.96 | 2.54 | 3.15 | 2.14 |
| Coffee | current | 0.79 | 0.75 | 0.75 | 1.03 | 0.99 | 0.90 | 0.83 | 0.83 | 0.90 | 1.20 |
| (kg) | constant | 2.86 | 2.74 | 2.74 | 3.65 | 3.47 | 3.00 | 2.74 | 2.90 | 3.13 | 3.80 |
| Tea | current | 1.36 | 1.38 | 1.31 | 1.33 | 1.29 | 1.26 | 1.27 | 1.05 | 0.97 | 1.10 |
| (kg) | constant | 4.89 | 5.02 | 4.75 | 4.70 | 4.55 | 4.19 | 4.17 | 3.67 | 3.38 | 3.46 |
| Rice | current | 136.5 | 152.8 | 143.3 | 137.7 | 136.3 | 163.2 | 205.8 | 201.6 | 186.9 | 144.0 |
| (metric ton) | constant | 491.0 | 557.7 | 521.1 | 488.3 | 479.9 | 544.0 | 677.0 | 707.4 | 649.0 | 454.3 |
| Sorghum | current | 42.6 | 45.6 | 48.6 | 48.2 | 47.2 | 51.7 | 50.4 | 46.5 | 50.1 | 51.8 |
| (metric ton) | constant | 153.2 | 166.4 | 176.7 | 170.9 | 166.2 | 172.3 | 165.8 | 163.2 | 174.0 | 163.4 |
| Maize | current | 45.9 | 51.4 | 54.7 | 55.8 | 55.0 | 59.4 | 49.9 | 49.1 | 53.9 | 58.4 |
| (metric ton) | constant | 165.1 | 187.6 | 198.9 | 197.9 | 193.7 | 198.0 | 164.1 | 172.3 | 187.2 | 184.2 |
| Wheat | current | 59.5 | 59.9 | 59.2 | 63.6 | 58.1 | 62.1 | 61.7 | 58.4 | 56.2 | 57.0 |
| (metric ton) | constant | 214.0 | 218.6 | 215.3 | 225.5 | 204.6 | 207.0 | 203.0 | 204.9 | 195.1 | 179.8 |
| Sugar | current | 0.06 | 0.06 | 0.18 | 0.13 | 0.04 | 0.04 | 0.04 | 0.04 | 0.07 | 0.08 |
| (kg) | constant | 0.21 | 0.22 | 0.67 | 0.45 | 0.16 | 0.13 | 0.14 | 0.15 | 0.25 | 0.26 |
| Beef | current | 0.68 | 0.71 | 0.67 | 0.84 | 0.88 | 1.02 | 1.04 | 1.09 | 1.22 | 1.30 |
| (kg) | constant | 2.45 | 2.61 | 2.43 | 2.98 | 3.11 | 3.41 | 3.42 | 3.81 | 4.25 | 4.11 |
| Bananas | current | 0.14 | 0.13 | 0.17 | 0.17 | 0.16 | 0.15 | 0.16 | 0.15 | 0.16 | 0.17 |
| (kg) | constant | 0.50 | 0.48 | 0.61 | 0.60 | 0.56 | 0.51 | 0.52 | 0.54 | 0.55 | 0.52 |
| Coconut Oil | current | 253.5 | 251.3 | 286.3 | 296.5 | 347.8 | 323.8 | 327.9 | 399.2 | 361.2 | 397.3 |
| (kg) | constant | 911.9 | 917.2 | 1041.1 | 1051.4 | 1224.7 | 1079.3 | 1078.6 | 1400.7 | 1254.2 | 1253.3 |
| Groundnut Oil | current | 330.7 | 274.5 | 268.4 | 315.3 | 323.8 | 296.2 | 283.2 | 270.7 | 331.6 | 378.6 |
| (metric ton) | constant | 1189.6 | 1001.8 | 976.0 | 1118.1 | 1140.1 | 987.3 | 931.6 | 949.8 | 1151.4 | 1194.3 |
| Palm Oil | current | 232.0 | 216.3 | 222.4 | 239.5 | 272.5 | 235.6 | 223.6 | 168.9 | 181.2 | 260.1 |
| (metric ton) | constant | 834.5 | 789.4 | 808.7 | 849.3 | 959.5 | 785.3 | 735.5 | 592.6 | 629.2 | 820.5 |
| Soybean Meal | current | 97 | 89 | 91 | 89 | 97 | 107 | 99 | 98 | 95 | 104 |
| (metric ton) | constant | 349 | 325 | 331 | 316 | 342 | 357 | 326 | 344 | 330 | 328 |
| Fishmeal | current | 131 | 148 | 145 | 161 | 190 | 160 | 134 | 129 | 172 | 197 |
| (metric ton) | constant | 471 | 540 | 527 | 571 | 669 | 533 | 441 | 453 | 597 | 621 |
| Cotton | current | 0.67 | 0.66 | 0.64 | 0.64 | 0.63 | 0.61 | 0.65 | 0.67 | 0.61 | 0.63 |
| (kg) | constant | 2.41 | 2.40 | 2.33 | 2.28 | 2.20 | 2.02 | 2.14 | 2.36 | 2.11 | 1.99 |
| Jute | current | 224.9 | 184.6 | 179.0 | 223.0 | 254.0 | 306.0 | 290.0 | 271.0 | 286.0 | 274.0 |
| (metric ton) | constant | 809.0 | 673.7 | 650.9 | 790.8 | 894.4 | 1020.0 | 954.0 | 950.0 | 993.1 | 864.4 |
| Wool | current | 1.94 | 1.93 | 2.27 | 2.37 | 1.98 | 2.18 | 1.88 | 1.71 | 1.63 | 1.46 |
| (kg) | constant | 6.99 | 7.05 | 8.26 | 8.40 | 6.97 | 7.28 | 6.17 | 6.01 | 5.64 | 4.62 |
| Rubber | current | 0.64 | 0.60 | 0.56 | 0.53 | 0.55 | 0.51 | 0.44 | 0.41 | 0.55 | 0.45 |
| (kg) | constant | 2.29 | 2.19 | 2.04 | 1.88 | 1.94 | 1.70 | 1.45 | 1.45 | 1.92 | 1.42 |
| Logs | current | 30.0 | 32.9 | 32.1 | 27.4 | 31.7 | 33.3 | 35.6 | 36.5 | 35.2 | 37.2 |
| (cu. meter) | constant | 107.9 | 120.1 | 116.7 | 97.2 | 111.6 | 111.0 | 117.1 | 128.1 | 122.2 | 117.4 |
| Coal | current | 10.06 | 10.08 | 10.06 | 10.14 | 10.22 | 10.24 | 10.57 | 10.80 | 11.48 | 14.77 |
| (metric ton) | constant | 36.19 | 36.79 | 36.58 | 35.96 | 35.99 | 34.13 | 34.77 | 37.90 | 39.86 | 46.59 |
| Petroleum | current | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| (barrel) | constant | 5.4 | 5.1 | 5.1 | 4.6 | 4.6 | 4.3 | 4.3 | 4.6 | 4.5 | 4.1 |
| Gasoline | current | X | X | X | X | X | X | 30.5 | 26.1 | 19.5 | 21.3 |
| (metric ton) | constant | X | X | X | X | X | X | 100.3 | 91.6 | 67.7 | 67.2 |
| Aluminum | current | 561 | 527 | 499 | 523 | 540 | 540 | 551 | 564 | 599 | 633 |
| (metric ton) | constant | 2018 | 1923 | 1815 | 1855 | 1901 | 1800 | 1813 | 1979 | 2080 | 1997 |
| Bauxite | current | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| (metric ton) | constant | 27.0 | 27.4 | 27.3 | 26.6 | 26.4 | 40.0 | 39.5 | 42.1 | 41.7 | 37.9 |
| Copper | current | 633 | 644 | 646 | 968 | 1290 | 1530 | 1138 | 1241 | 1466 | 1413 |
| (metric ton) | constant | 2277 | 2350 | 2349 | 3433 | 4542 | 5100 | 3743 | 4354 | 5090 | 4457 |
| Lead | current | 176 | 154 | 174 | 278 | 317 | 262 | 229 | 240 | 289 | 304 |
| (metric ton) | constant | 633 | 562 | 633 | 986 | 1116 | 873 | 753 | 842 | 1003 | 959 |
| Tin | current | 2447 | 2471 | 2507 | 3408 | 3893 | 3574 | 3331 | 3126 | 3428 | 3673 |
| (metric ton) | constant | 8802 | 9018 | 9116 | 12085 | 13708 | 11913 | 10957 | 10968 | 11903 | 11587 |
| Zinc | current | 214 | 185 | 212 | 324 | 311 | 282 | 273 | 262 | 287 | 295 |
| (metric ton) | constant | 770 | 675 | 771 | 1149 | 1095 | 940 | 898 | 919 | 997 | 931 |
| Iron Ore | current | 11.5 | 10.8 | 10.1 | 10.1 | 10.1 | 9.9 | 8.7 | 8.4 | 8.4 | 9.3 |
| (metric ton) | constant | 41.4 | 39.4 | 36.7 | 35.8 | 35.6 | 33.0 | 28.6 | 29.5 | 29.2 | 29.3 |
| Manganese Ore | current | 0.87 | 0.86 | 0.81 | 0.68 | 0.75 | 0.76 | 0.72 | 0.62 | 0.52 | 0.54 |
| (10 kg Mn) | constant | 3.13 | 3.12 | 2.95 | 2.42 | 2.65 | 2.53 | 2.38 | 2.18 | 1.81 | 1.72 |
| Nickel | current | 1711 | 1761 | 1742 | 1742 | 1735 | 1739 | 1936 | 2075 | 2363 | 2846 |
| (metric ton) | constant | 6155 | 6427 | 6335 | 6177 | 6109 | 5797 | 6368 | 7281 | 8205 | 8978 |
| Steel | current | 108.2 | 109.5 | 109.5 | 109.5 | 107.3 | 109.3 | 102.0 | 94.5 | 100.5 | 124.9 |
| (metric ton) | constant | 389.2 | 399.6 | 398.2 | 388.3 | 377.8 | 364.3 | 335.5 | 331.6 | 349.0 | 394.0 |
| Phosphate Rock | current | 13.0 | 11.5 | 11.5 | 12.5 | 14.0 | 13.0 | 12.0 | 11.5 | 11.3 | 11.0 |
| (metric ton) | constant | 46.8 | 42.0 | 41.8 | 44.3 | 49.3 | 43.3 | 39.5 | 40.4 | 39.2 | 34.7 |

# Table 1.3

| 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 99 | 124 | 178 | 118 | 109 | 120 | 92 | 92 | 117 | 95 | 74 | 80 | 76 |
| 58 | 58 | 62 | 57 | 48 | 89 | 139 | 88 | 82 | 67 | 58 | 61 | 64 | 71 |
| 112 | 109 | 187 | 216 | 148 | 119 | 101 | 103 | 97 | 107 | 119 | 88 | 98 | 92 |
| 108 | 96 | 165 | 152 | 89 | 93 | 107 | 96 | 99 | 84 | 84 | 69 | 85 | 96 |
| 126 | 167 | 179 | 381 | 240 | 147 | 105 | 92 | 103 | 223 | 151 | 91 | 96 | 66 |
| 104 | 98 | 130 | 116 | 89 | 110 | 103 | 95 | 102 | 108 | 98 | 88 | 102 | 97 |
| 80 | 72 | 105 | 101 | 67 | 88 | 92 | 79 | 125 | 139 | 109 | 111 | 107 | 118 |
| 127 | 115 | 140 | 152 | 115 | 110 | 105 | 91 | 105 | 108 | 102 | 95 | 98 | 91 |

| 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.54 | 0.64 | 1.13 | 1.56 | 1.25 | 2.05 | 3.79 | 3.40 | 3.29 | 2.60 | 2.08 | 1.74 | 2.12 | 2.40 |
| 1.56 | 1.72 | 2.51 | 2.78 | 1.94 | 3.13 | 5.38 | 4.10 | 3.58 | 2.60 | 2.17 | 1.84 | 2.32 | X |
| 0.99 | 1.12 | 1.53 | 1.62 | 1.85 | 3.30 | 6.79 | 3.20 | 3.89 | 4.58 | 3.87 | 3.17 | 3.15 | 3.30 |
| 2.87 | 2.98 | 3.39 | 2.87 | 2.89 | 5.05 | 9.62 | 3.85 | 4.21 | 4.58 | 4.04 | 3.37 | 3.45 | X |
| 1.05 | 1.05 | 1.06 | 1.40 | 1.39 | 1.54 | 2.69 | 2.19 | 2.16 | 2.23 | 2.02 | 1.93 | 2.33 | 3.46 |
| 3.06 | 2.97 | 2.35 | 2.49 | 2.16 | 2.35 | 3.81 | 2.64 | 2.34 | 2.23 | 2.11 | 2.05 | 2.55 | X |
| 129.0 | 147.0 | 350.0 | 542.0 | 363.1 | 254.5 | 272.2 | 367.5 | 334.2 | 433.9 | 482.8 | 292.9 | 276.9 | 252.1 |
| 375.0 | 389.9 | 777.8 | 961.0 | 566.5 | 389.7 | 385.6 | 442.8 | 359.0 | 433.9 | 504.0 | 311.3 | 303.3 | X |
| 55.7 | 56.0 | 93.0 | 121.0 | 111.9 | 105.2 | 88.4 | 93.8 | 108.1 | 128.9 | 126.4 | 108.5 | 128.8 | 118.2 |
| 161.9 | 148.5 | 206.7 | 214.5 | 174.6 | 161.1 | 125.2 | 113.0 | 117.3 | 128.9 | 131.9 | 115.3 | 141.1 | X |
| 58.4 | 56.0 | 98.0 | 132.0 | 119.6 | 112.4 | 95.3 | 100.7 | 115.5 | 125.3 | 130.8 | 109.3 | 136.0 | 135.9 |
| 169.8 | 148.5 | 217.8 | 234.0 | 186.6 | 172.1 | 135.0 | 121.3 | 125.1 | 125.3 | 136.5 | 116.2 | 149.0 | X |
| 62.1 | 69.1 | 136.8 | 178.0 | 138.4 | 122.7 | 95.5 | 124.9 | 156.3 | 168.3 | 154.6 | 132.6 | 137.3 | 140.2 |
| 180.5 | 183.3 | 304.0 | 315.6 | 215.9 | 187.9 | 135.3 | 150.5 | 169.3 | 168.3 | 161.4 | 140.9 | 150.4 | X |
| 0.10 | 0.16 | 0.21 | 0.65 | 0.45 | 0.25 | 0.18 | 0.17 | 0.21 | 0.63 | 0.37 | 0.19 | 0.19 | 0.11 |
| 0.29 | 0.43 | 0.46 | 1.16 | 0.70 | 0.39 | 0.25 | 0.21 | 0.23 | 0.63 | 0.39 | 0.20 | 0.20 | X |
| 1.35 | 1.48 | 2.01 | 1.58 | 1.33 | 1.58 | 1.51 | 2.14 | 2.88 | 2.76 | 2.48 | 2.39 | 2.44 | 2.27 |
| 3.91 | 3.93 | 4.47 | 2.81 | 2.07 | 2.42 | 2.13 | 2.58 | 3.08 | 2.76 | 2.58 | 2.54 | 2.67 | X |
| 0.14 | 0.16 | 0.17 | 0.18 | 0.25 | 0.26 | 0.28 | 0.29 | 0.33 | 0.38 | 0.40 | 0.37 | 0.43 | 0.37 |
| 0.41 | 0.43 | 0.37 | 0.33 | 0.39 | 0.39 | 0.39 | 0.35 | 0.35 | 0.38 | 0.42 | 0.40 | 0.47 | X |
| 370.5 | 234.2 | 513.0 | 998.0 | 393.5 | 418.0 | 578.2 | 683.3 | 984.5 | 673.8 | 569.9 | 464.4 | 729.9 | 1155.0 |
| 1077.0 | 621.2 | 1140.0 | 1769.5 | 613.9 | 640.1 | 819.0 | 823.1 | 1066.6 | 673.8 | 594.9 | 493.5 | 799.5 | X |
| 440.7 | 425.9 | 546.2 | 1076.8 | 857.0 | 741.0 | 852.3 | 1079.2 | 888.7 | 858.8 | 1043.0 | 584.9 | 710.9 | 1017.0 |
| 1281.1 | 1129.7 | 1213.8 | 1909.2 | 1137.0 | 1134.8 | 1207.2 | 1300.2 | 962.8 | 858.8 | 1088.7 | 621.6 | 778.6 | X |
| 261.1 | 217.3 | 377.5 | 669.0 | 434.2 | 406.5 | 530.0 | 600.2 | 653.8 | 583.5 | 570.7 | 445.1 | 501.4 | 729.0 |
| 759.0 | 576.4 | 838.9 | 1186.2 | 677.4 | 622.5 | 750.7 | 723.1 | 708.3 | 583.5 | 595.1 | 473.0 | 549.2 | X |
| 105 | 129 | 302 | 184 | 155 | 198 | 230 | 213 | 243 | 262 | 253 | 219 | 238 | 197 |
| 305 | 342 | 671 | 326 | 242 | 303 | 326 | 257 | 263 | 262 | 264 | 232 | 260 | X |
| 167 | 239 | 542 | 372 | 245 | 376 | 454 | 410 | 395 | 504 | 468 | 353 | 453 | 373 |
| 485 | 634 | 1204 | 660 | 382 | 576 | 643 | 494 | 428 | 504 | 489 | 375 | 496 | X |
| 0.74 | 0.79 | 1.36 | 1.42 | 1.16 | 1.69 | 1.55 | 1.57 | 1.69 | 2.05 | 1.85 | 1.60 | 1.85 | 1.79 |
| 2.15 | 2.10 | 3.01 | 2.51 | 1.81 | 2.59 | 2.20 | 1.89 | 1.83 | 2.05 | 1.93 | 1.70 | 2.03 | X |
| 286.0 | 299.0 | 289.0 | 353.0 | 371.0 | 295.6 | 320.9 | 398.4 | 387.4 | 313.6 | 275.0 | 285.8 | 302.2 | 530.8 |
| 831.4 | 793.1 | 642.2 | 625.9 | 578.8 | 452.7 | 454.5 | 523.7 | 419.7 | 313.6 | 287.1 | 303.7 | 331.0 | X |
| 1.37 | 2.40 | 5.14 | 3.67 | 2.74 | 3.41 | 3.58 | 3.75 | 4.43 | 4.60 | 2.48 | 3.93 | 3.64 | 3.67 |
| 3.99 | 6.37 | 11.41 | 6.51 | 4.28 | 5.22 | 5.07 | 4.52 | 4.80 | 4.60 | 4.46 | 4.17 | 3.99 | X |
| 0.37 | 0.37 | 0.78 | 0.77 | 0.67 | 0.87 | 0.91 | 1.05 | 1.29 | 1.54 | 1.17 | 0.91 | 1.15 | 1.02 |
| 1.07 | 0.99 | 1.73 | 1.37 | 1.04 | 1.33 | 1.29 | 1.27 | 1.39 | 1.54 | 1.22 | 0.96 | 1.25 | X |
| 38.0 | 37.6 | 65.6 | 78.6 | 59.3 | 79.6 | 89.8 | 91.8 | 160.2 | 192.9 | 144.6 | 145.2 | 135.2 | 151.0 |
| 110.5 | 99.7 | 145.8 | 139.4 | 92.5 | 121.9 | 127.2 | 110.6 | 173.6 | 192.9 | 150.9 | 154.3 | 148.1 | X |
| 17.35 | 19.16 | 20.90 | 44.52 | 54.27 | 53.56 | 54.26 | 55.74 | 56.50 | 55.70 | 58.05 | 56.40 | 57.47 | 57.77 |
| 50.43 | 50.82 | 46.44 | 78.94 | 84.67 | 82.02 | 76.86 | 67.16 | 61.21 | 55.70 | 60.63 | 59.94 | 62.95 | X |
| 1.7 | 1.9 | 2.7 | 11.2 | 10.9 | 11.7 | 12.8 | 12.9 | 18.6 | 30.5 | 34.4 | 33.2 | 29.1 | 28.5 |
| 4.9 | 5.0 | 6.0 | 19.9 | 17.0 | 17.9 | 18.1 | 15.5 | 20.2 | 30.5 | 35.9 | 35.3 | 31.9 | X |
| 25.1 | 30.4 | 87.8 | 131.1 | 120.3 | 137.9 | 131.6 | 160.0 | 335.0 | 358.0 | 354.1 | 323.6 | 283.9 | 259.1 |
| 73.0 | 80.6 | 195.1 | 232.4 | 187.7 | 211.2 | 186.4 | 192.8 | 362.9 | 358.0 | 369.6 | 343.9 | 311.0 | X |
| 639 | 582 | 551 | 752 | 877 | 978 | 1132 | 1170 | 1310 | 1534 | 1676 | 1676 | 1712 | 1786 |
| 1858 | 1544 | 1224 | 1333 | 1368 | 1498 | 1603 | 1410 | 1419 | 1534 | 1749 | 1781 | 1875 | X |
| 12.0 | 12.0 | 12.5 | 23.2 | 25.3 | 27.2 | 30.8 | 34.2 | 36.6 | 41.2 | 40.0 | 36.0 | 34.7 | 33.2 |
| 34.9 | 31.8 | 27.8 | 41.1 | 39.5 | 41.7 | 43.6 | 41.3 | 39.6 | 41.2 | 41.8 | 38.3 | 38.0 | X |
| 1080 | 1071 | 1786 | 2059 | 1237 | 1401 | 1309 | 1365 | 1985 | 2183 | 1742 | 1480 | 1592 | 1379 |
| 3140 | 2841 | 3969 | 3650 | 1930 | 2145 | 1854 | 1645 | 2151 | 2183 | 1818 | 1573 | 1744 | X |
| 254 | 302 | 430 | 593 | 417 | 445 | 618 | 662 | 1208 | 906 | 727 | 546 | 425 | 444 |
| 738 | 801 | 956 | 1051 | 651 | 681 | 875 | 798 | 1309 | 906 | 759 | 580 | 466 | X |
| 3501 | 3770 | 4828 | 8201 | 6870 | 7582 | 10762 | 12908 | 15458 | 16775 | 14159 | 12826 | 12988 | 12273 |
| 10177 | 10000 | 10729 | 14541 | 10718 | 11611 | 15244 | 15552 | 16748 | 16775 | 14780 | 13630 | 14226 | X |
| 309 | 377 | 851 | 1239 | 743 | 712 | 591 | 593 | 742 | 761 | 846 | 745 | 764 | 922 |
| 898 | 1000 | 1891 | 2197 | 1159 | 1090 | 837 | 714 | 804 | 761 | 883 | 792 | 837 | X |
| 10.5 | 10.8 | 10.1 | 12.8 | 19.3 | 16.1 | 13.4 | 15.9 | 14.3 | 17.6 | 18.5 | 19.3 | 21.6 | 17.1 |
| 30.5 | 28.7 | 22.4 | 22.7 | 30.1 | 24.7 | 19.0 | 19.2 | 15.5 | 17.6 | 19.3 | 20.5 | 23.7 | X |
| 0.63 | 0.64 | 0.75 | 1.12 | 1.38 | 1.45 | 1.48 | 1.43 | 1.38 | 1.57 | 1.68 | 1.64 | 1.52 | 1.43 |
| 1.83 | 1.68 | 1.66 | 1.99 | 2.15 | 2.22 | 2.10 | 1.72 | 1.49 | 1.57 | 1.75 | 1.74 | 1.66 | X |
| 2932 | 3080 | 3373 | 3825 | 4570 | 4973 | 5203 | 4609 | 5986 | 7528 | 7560 | 7055 | 7055 | 7055 |
| 8523 | 8170 | 7496 | 6782 | 7129 | 7615 | 7370 | 5553 | 6485 | 7528 | 7891 | 7497 | 7727 | X |
| 137.1 | 157.4 | 207.9 | 250.0 | 300.8 | 329.5 | 320.0 | 391.8 | 428.3 | 466.0 | 375.5 | 402.4 | 331.8 | 353.2 |
| 398.6 | 417.5 | 462.0 | 443.3 | 469.3 | 504.6 | 453.3 | 472.1 | 464.0 | 466.0 | 392.0 | 427.6 | 363.4 | X |
| 11.3 | 11.5 | 13.8 | 54.5 | 67.0 | 36.0 | 30.5 | 29.0 | 33.0 | 46.7 | 49.5 | 42.4 | 36.9 | 38.3 |
| 32.9 | 30.5 | 30.7 | 96.6 | 104.5 | 55.1 | 43.2 | 34.9 | 35.8 | 46.7 | 51.7 | 45.1 | 40.4 | X |

**Source:** The World Bank. X = not available. For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 1.1 Gross National Product, 1960–83

**Sources:** GNP: The World Bank, *The World Bank Atlas 1985,* (The World Bank, Washington, 1985). GNP growth rates: unpublished World Bank data. Gross Domestic Product data: The World Bank, *World Development Report* 1985 (Oxford University Press, New York, 1985), pp. 178–179.

Gross National Product is the sum of two components: the Gross Domestic Product, the final output of goods and services produced by the domestic economy (including net exports of goods and non-factor services), and net factor income from abroad. Net factor income from abroad is income residents receive on a net basis from abroad for factor services (labor, investment, and interest). Gross Domestic Product was estimated by the production method. This method sums the final outputs of the various sectors of the economy (agriculture, manufacturing, government services, etc.) from which the value of the inputs to production have been subtracted.

Gross national product in domestic currency was converted to U.S. dollars using a three-year average exchange rate, adjusted for domestic and U.S. inflation.

The average annual percentage change of GNP was calculated by fitting a least square regression line to the logarithmic values for GNP.

The agricultural sector includes forestry, hunting, and fishing; the industrial sector includes mining, manufacturing, construction, electricity, water, and gas; and the service sector summarizes all other economic activity. Because a sizeable fraction of agricultural, forestry, hunting, and fishing output does not enter the money economy (especially in developing countries with large subsistence populations), the output of the agricultural sector and of GDP are often difficult to estimate.

The Gross National Product data are produced by countries that use a market-oriented system of national accounts. Over the years, World Bank economists have reviewed the national income accounting practices of developing countries and adjusted their national GNP figures to fit common definitions. The Economic Analysis and Projection Department of the Bank reviews country data annually and futher adjusts them as needed.

For additional information on procedures used to estimate GNP, see the Technical Notes, World Development Indicators Annex, *World Development Report.*

### Table 1.2 Labor Force, 1965–2000

**Sources:** Total labor force data: U.N. Food and Agriculture Organization (FAO), *FAO Production Yearbook 1983* (U.N. Food and Agriculture Organization, Rome, 1984), pp. 61–72. Labor force by economic sector and labor force growth rates: The World Bank, *World Development Report 1985* (Oxford University Press, New York, 1985), pp. 214–215.

The labor force is made up of all persons who work to produce economic goods and services. It includes all employed persons (employers, persons working on their own account, salaried employees, wage earners, unpaid family workers, members of producer cooperatives and armed forces) and all the unemployed, both experienced workers and those looking for work for the first time.

The labor force sectors correspond to the production sectors used in Table 1.1.

Most of the data were originally compiled by the International Labor Organization (ILO) from national censuses and labor surveys. The ILO standardizes labor force data to a base year (1970) and prepares estimates and projections of the size and sectoral composition of the labor force for the years 1980, 1990, and 2000. The ILO estimated the size of the 1970 labor force using data collected from population censuses and labor force and demographic surveys. Data for each country were adjusted to fit the ILO definition of economically active. The most difficult groups to estimate were the unpaid household workers (mostly female) and young people working on family farms.

When data for 1970 were unavailable, estimates were made based on experiences in culturally and socially similar countries. For example, the ILO estimated missing data for Jordan, Saudi Arabia, Yemen, and Democratic Yemen by analyzing recent results of censuses from ten other Islamic countries.

For a complete discussion of definitions and methods, see *Labor Force Estimates and Projections 1950–2000,* (International Labor Organization, Geneva, 1977). Data for the 1980 base year will be published in early 1986.

### Table 1.3 World Commodity Prices and Indexes, 1961–84

**Sources:** The World Bank, *Commodity Trade and Price Trends* (The Johns Hopkins University Press, Baltimore, Maryland, 1985), and unpublished World Bank data.

Price data are compiled from major marketplaces for standard grades of each commodity. For example, the gasoline series refers to 91/92 octane regular gasoline, in barges, fob (free on board) Rotterdam.

Average monthly current prices in local currencies were converted to U.S. dollars using the monthly average exchange rate. The monthly average U.S. dollar figures were averaged to produce an annual average dollar figure. The resulting U.S. dollar series was adjusted to 1980 constant dollars using the Manufacturing Unit Value (MUV) Index. The MUV Index is a composite price index of all manufactured goods traded internationally.

The aggregate price indexes have the following components:

1. All Foods: beverages, cereals, fats and oils, other foods;
2. Beverages: coffee, cocoa, tea;
3. Cereals: maize, rice, wheat, grain sorghum;
4. Fats and Oils: palm oil, coconut oil, groundnut oil, soybeans, copra, groundnut meal, soybean meal;
5. Other Foods: sugar, beef, bananas, oranges;
6. Non-food Agriculturals: cotton, jute, rubber, tobacco;
7. Timber: logs;
8. Metals and Minerals: copper, tin, nickel, bauxite, aluminum, iron ore, manganese ore, lead, zinc, phosphate rock.

# 2. Population and Health

The tables in this chapter deal with the size and growth of population and include a few important indicators of the state of health and education. Tables 2.1 and 2.2 present national, regional, and global data on population size and growth and on two major factors that determine population change—birth and death rates. These statistics and those on age distribution (Table 2.3) and infant mortality (Table 2.4) are taken from periodic assessments by the Population Division of the U.N. Department of International Economic and Social Affairs.

Of the 146 countries shown in these tables, 128 conducted a national population census or major population survey between 1970 and 1982; 14 conducted a census before 1970; 3 (Somalia, Oman, and Lao PDR) have not conducted a modern census, and 1 country, Ethiopia, conducted its first census in 1984. Although the number and frequency of national censuses have increased over the past decade, their quality is sometimes poor. In many African countries they are inadequate and the U.N. Population Division must substantially adjust the figures. Censuses are generally good in Latin America. In Asia, the results from recent censuses in India and China—the world's two most populous countries—could not be fully incorporated into the U.N.'s 1982 assessment.

Crude birth and death rates along with net migration are the three basic determinants of population change in a country. When birth rates remain relatively high and death rates decline, the population increases rapidly, as many developing countries have experienced in the past 20 years. When both birth and death rates decline, the population growth rate also declines. In Australia, Canada, the United States, and some of the oil-rich Middle East countries, immigration has considerably increased the population. In other countries—Afghanistan, Ethiopia, Lebanon, and Viet Nam, for example—emigration has had the opposite effect.

Crude birth and death rates are heavily influenced by the age structures of the population, as shown in Table 2.3. In Kenya, Botswana, Rwanda, and many other African countries, more than 45 percent of the population is under 15 years of age and only 1 or 2 percent is over 65 years. The reverse is true in Europe: in Sweden, Switzerland, Denmark, and Norway, at least 15 percent of the population is over 65 years of age and about the same percent is under 15 years. Age distribution also has important implications for economic development (essentially, the middle group must support the other two groups by providing services such as education, jobs, social welfare, and health care).

In addition to crude birth and death rates, Table 2.2 gives figures for two synthetic indicators used to analyze population and health trends. The "total fertility rate" is an estimate of the number of children an average woman would have if current age-specific fertility rates remain constant during her reproductive years. Total fertility rates have fallen worldwide from 4.9 in 1960–65 to 3.55 in 1980–85. Currently, the highest rates are for women in Kenya (8.1), Jordan (7.4), Rwanda (7.3), and Libya (7.2); they are lowest in Switzerland (1.3), the Federal Republic of Germany (1.4), Luxembourg (1.4), and the Netherlands (1.4).

"Life expectancy at birth" is a common measure of mortality. Many developing countries have achieved impressive gains in life expectancy at birth largely because infant and childhood mortality have been reduced. In Africa, infant mortality declined 27 percent between 1960–65 and 1980–85, in Asia by 35 percent, and in South America by 37 percent. But in many countries one of ten babies still dies in the first year of life.

Food supplies are inadequate in many countries, as Table 2.4 shows. India, for example, is able to supply only about 90 percent of the calories needed to feed its population. Yet in other countries—Libya, Ireland, and Bulgaria, for example—calorie supplies, as estimated by the U.N. Food and Agriculture Organization, are in substantial excess of requirements. The "minimum daily calorie requirement" is the energy intake that is adequate to meet the needs of an average healthy person. It is important to note, however, that the figures are national averages and therefore do not reflect sharp differences in access to food between the rich and the poor in a country. Nor do they reflect the amounts of dietary energy lost or wasted during storage, preparation, and cooking of food.

The growing use of contraception, also shown in Table 2.4, indicates that many families desire to control the number and spacing of children. It also indicates the growing demand by women for preventive health care.

Most countries attempt to provide basic education to all children. An important indicator of their success in achieving this social goal is the percentage of school-age children who actually attend school, as shown in Table 2.5.

# Table 2.1 ESTIMATED SIZE AND GROWTH OF POPULATION,

| | Estimated Population (thousands) | | | Estimated Average Annual Growth of Population (percent) | | | |
|---|---|---|---|---|---|---|---|
| | 1960 | 1985 | 2000 | 1960–65 | 1970–75 | 1980–85 | 2000–05 |
| **WORLD** | **3013816** | **4842048** | **6127117** | **1.96** | **2.03** | **1.67** | **1.39** |
| **AFRICA** | **277541** | **553210** | **877439** | **2.44** | **2.74** | **3.01** | **2.96** |
| Algeria | 10800 | 21993 | 35194 | 1.98 | 3.06 | 3.28 | 2.50 |
| Angola | 4816 | 8754 | 13234 | 1.45 | 3.08 | 2.51 | 2.81 |
| Benin | 2251 | 4005 | 6381 | 1.64 | 2.33 | 2.86 | 3.10 |
| Botswana | 481 | 1079 | 1865 | 2.63 | 3.77 | 3.46 | 3.65 |
| Burkina Faso | 4279 | 6939 | 10542 | 1.65 | 1.85 | 2.34 | 2.82 |
| Burundi | 2927 | 4631 | 6951 | 1.87 | 1.62 | 2.67 | 2.51 |
| Cameroon | 5545 | 9714 | 14424 | 1.95 | 2.24 | 2.54 | 2.62 |
| Cape Verde | 195 | 321 | 382 | 2.80 | 1.97 | 1.36 | 0.91 |
| Central African Rep | 1605 | 2567 | 3736 | 1.48 | 1.85 | 2.29 | 2.58 |
| Chad | 3064 | 5018 | 7304 | 1.69 | 1.97 | 2.28 | 2.57 |
| Comoros | 215 | 457 | 715 | 2.25 | 3.40 | 3.04 | 2.36 |
| Congo | 972 | 1740 | 2646 | 2.06 | 2.37 | 2.59 | 2.84 |
| Djibouti | 78 | 293 | X | X | 5.60 | 2.00 | X |
| Egypt | 25490 | 46800 | 65200 | 2.50 | 1.95 | 2.52 | 1.89 |
| Equatorial Guinea | 252 | 392 | 559 | 1.33 | 1.78 | 2.15 | 2.40 |
| Ethiopia | 20021 | 36454 | 58407 | 2.32 | 2.65 | 2.60 | 3.02 |
| Gabon | 867 | 1166 | 1611 | 0.87 | 1.08 | 1.64 | 2.74 |
| Gambia | 374 | 643 | 898 | 2.28 | 2.23 | 1.94 | 2.32 |
| Ghana | 6772 | 13478 | 21923 | 2.79 | 2.58 | 3.25 | 2.93 |
| Guinea | 3271 | 5429 | 7935 | 1.68 | 2.01 | 2.33 | 2.56 |
| Guinea-Bissau | 540 | 889 | 1241 | -0.56 | 3.55 | 1.91 | 2.32 |
| Ivory Coast | 3731 | 9797 | 15581 | 3.80 | 3.95 | 3.44 | 2.92 |
| Kenya | 7903 | 20600 | 38534 | 3.48 | 3.87 | 4.12 | 3.89 |
| Lesotho | 871 | 1520 | 2251 | 2.01 | 2.18 | 2.53 | 2.61 |
| Liberia | 1047 | 2191 | 3564 | 2.58 | 2.94 | 3.16 | 3.18 |
| Libya | 1349 | 3604 | 6072 | 3.70 | 4.03 | 3.84 | 3.00 |
| Madagascar | 5362 | 10012 | 15552 | 2.18 | 2.48 | 2.80 | 2.93 |
| Malawi | 3529 | 7016 | 11669 | 2.38 | 2.69 | 3.23 | 3.33 |
| Mali | 4636 | 8053 | 12363 | 1.93 | 2.03 | 2.78 | 2.74 |
| Mauritania | 981 | 1888 | 2999 | 2.35 | 2.61 | 2.93 | 3.01 |
| Mauritius | 660 | 1050 | 1298 | 3.18 | 0.47 | 1.90 | 1.09 |
| Morocco | 11626 | 23602 | 36325 | 2.73 | 2.45 | 3.26 | 2.40 |
| Mozambique | 6546 | 14085 | 21779 | 2.08 | 3.55 | 3.05 | 2.87 |
| Niger | 3234 | 6115 | 9750 | 2.89 | 2.36 | 2.82 | 3.15 |
| Nigeria | 42305 | 95198 | 61930 | 2.80 | 3.35 | 3.34 | 3.49 |
| Rwanda | 2753 | 6115 | 10565 | 2.96 | 3.19 | 3.46 | 3.58 |
| Senegal | 3041 | 6520 | 10036 | 2.64 | 3.48 | 2.66 | 2.92 |
| Sierra Leone | 2475 | 3602 | 4868 | 1.33 | 1.43 | 1.77 | 2.12 |
| Somalia | 2271 | 5552 | 7079 | 1.98 | 2.27 | 3.71 | 2.76 |
| South Africa | 18281 | 32392 | 46918 | 2.12 | 2.27 | 2.48 | 2.28 |
| Sudan | 11165 | 21550 | 32926 | 2.03 | 2.89 | 2.86 | 2.54 |
| Swaziland | 338 | 649 | 1041 | 2.31 | 2.52 | 3.03 | 3.05 |
| Tanzania, United Rep | 10026 | 22499 | 39129 | 2.89 | 3.25 | 3.52 | 3.62 |
| Togo | 1514 | 2923 | 4599 | 1.44 | 2.17 | 2.86 | 3.03 |
| Tunisia | 4221 | 7209 | 9725 | 1.85 | 1.81 | 2.41 | 1.56 |
| Uganda | 6562 | 15697 | 26774 | 4.08 | 2.68 | 3.50 | 3.36 |
| Zaire | 17755 | 33052 | 52410 | 1.90 | 2.65 | 2.94 | 3.10 |
| Zambia | 3141 | 6666 | 11237 | 2.80 | 2.89 | 3.31 | 3.49 |
| Zimbabwe | 3604 | 8767 | 15132 | 4.13 | 3.17 | 3.50 | 3.59 |
| **NORTH AMERICA** | **268584** | **400802** | **488073** | **1.85** | **1.57** | **1.38** | **1.13** |
| Barbados | 231 | 265 | 307 | 0.39 | 0.39 | 0.82 | 0.90 |
| Canada | 17909 | 25605 | 29435 | 1.85 | 1.20 | 1.21 | 0.69 |
| Costa Rica | 1236 | 2600 | 3596 | 3.63 | 2.52 | 2.64 | 1.72 |
| Cuba | 7029 | 10038 | 11718 | 2.10 | 1.70 | 0.62 | 0.76 |
| Dominican Rep | 3224 | 6243 | 8407 | 2.91 | 2.85 | 2.32 | 1.74 |
| El Salvador | 2574 | 5552 | 8708 | 3.09 | 2.91 | 2.93 | 2.62 |
| Guatemala | 3966 | 8403 | 12739 | 3.03 | 3.07 | 2.92 | 2.44 |
| Haiti | 3723 | 6585 | 9860 | 2.11 | 2.26 | 2.51 | 2.70 |
| Honduras | 1943 | 4372 | 6978 | 3.41 | 3.18 | 3.39 | 3.08 |
| Jamaica | 1629 | 2323 | 2849 | 1.55 | 1.78 | 1.36 | 1.13 |
| Mexico | 37073 | 78996 | 109180 | 3.20 | 3.23 | 2.59 | 1.70 |
| Nicaragua | 1493 | 3272 | 5261 | 3.19 | 3.20 | 3.32 | 2.72 |
| Panama | 1148 | 2180 | 2893 | 2.89 | 2.65 | 2.17 | 1.48 |
| Trinidad and Tobago | 843 | 1118 | 1321 | 2.90 | 1.04 | 0.92 | 1.00 |
| United States | 180671 | 237660 | 268079 | 1.46 | 1.04 | 0.86 | 0.68 |
| **SOUTH AMERICA** | **146874** | **268825** | **359581** | **2.75** | **2.33** | **2.24** | **1.63** |
| Argentina | 20616 | 30564 | 37197 | 1.55 | 1.67 | 1.58 | 1.13 |
| Bolivia | 3428 | 6371 | 9724 | 2.27 | 2.48 | 2.69 | 2.82 |
| Brazil | 72594 | 135564 | 179487 | 2.99 | 2.39 | 2.23 | 1.51 |
| Chile | 7585 | 12074 | 14934 | 2.30 | 1.70 | 1.68 | 1.15 |
| Colombia | 15538 | 28714 | 37999 | 3.07 | 2.16 | 2.15 | 1.50 |
| Ecuador | 4422 | 9380 | 14596 | 2.99 | 2.91 | 3.13 | 2.57 |
| Guyana | 569 | 953 | 1196 | 2.52 | 1.89 | 1.95 | 1.21 |
| Paraguay | 1778 | 3681 | 5405 | 2.54 | 3.19 | 3.00 | 2.16 |
| Peru | 9931 | 19698 | 27952 | 2.88 | 2.78 | 2.60 | 1.91 |
| Suriname | 290 | 353 | 423 | 2.72 | -0.29 | 0.06 | 1.58 |
| Uruguay | 2538 | 3012 | 3364 | 1.19 | 0.14 | 0.70 | 0.65 |
| Venezuela | 7550 | 18386 | 27207 | 3.88 | 3.58 | 3.26 | 2.14 |

# 1960–2005 Table 2.1

| | Estimated Population (thousands) | | | Estimated Average Annual Growth of Population (percent) | | | |
|---|---|---|---|---|---|---|---|
| | 1960 | 1985 | 2000 | 1960–65 | 1970–75 | 1980–85 | 2000–05 |
| **ASIA** | **1665573** | **2824008** | **3543693** | **2.14** | **2.35** | **1.73** | **1.22** |
| Afghanistan | 10016 | 14636 | 24180 | 2.08 | 2.39 | 0.04 | 1.95 |
| Bahrain | 156 | 431 | 688 | 4.04 | 4.28 | 4.32 | 2.19 |
| Bangladesh | 51585 | 101147 | 145800 | 2.47 | 2.77 | 2.74 | 2.04 |
| Bhutan | 867 | 1417 | 1893 | 1.81 | 2.05 | 2.03 | 1.71 |
| Burma | 21780 | 39487 | 55186 | 2.28 | 2.40 | 2.52 | 1.94 |
| China | 667322 | 1063105 | 1255656 | 1.76 | 2.37 | 1.17 | 0.95 |
| Cyprus | 573 | 667 | 759 | 0.32 | −0.19 | 1.15 | 0.77 |
| India | 431463 | 761175 | 961531 | 2.50 | 2.31 | 1.99 | 1.09 |
| Indonesia | 96194 | 164887 | 204486 | 2.14 | 2.41 | 1.76 | 1.15 |
| Iran | 20301 | 45106 | 65549 | 3.41 | 3.21 | 3.02 | 1.97 |
| Iraq | 6847 | 15676 | 24926 | 3.05 | 3.27 | 3.43 | 2.71 |
| Israel | 2114 | 4298 | 5376 | 3.85 | 3.00 | 2.05 | 1.22 |
| Japan | 94096 | 120072 | 127683 | 0.99 | 1.33 | 0.57 | 0.29 |
| Jordan | 1695 | 3509 | 6400 | 2.93 | 2.46 | 3.66 | 3.70 |
| Kampuchea, Dem | 5433 | 7393 | 9918 | 2.45 | 0.46 | 2.89 | 0.89 |
| Korea, Dem People's Rep | 10526 | 20082 | 27256 | 2.79 | 2.64 | 2.31 | 1.62 |
| Korea, Rep | 25003 | 40872 | 49485 | 2.64 | 2.00 | 1.39 | 0.88 |
| Kuwait | 278 | 1785 | 2969 | 10.53 | 6.04 | 5.26 | 2.43 |
| Lao People's Dem Rep | 2355 | 4423 | 6213 | 2.37 | 2.54 | 2.51 | 1.93 |
| Lebanon | 1857 | 2668 | 3617 | 2.94 | 2.28 | −0.01 | 1.67 |
| Malaysia | 8205 | 15551 | 20615 | 3.00 | 2.50 | 2.29 | 1.35 |
| Mongolia | 931 | 1900 | 2673 | 2.78 | 2.93 | 2.66 | 1.85 |
| Nepal | 9404 | 16482 | 23048 | 1.90 | 2.47 | 2.33 | 1.94 |
| Oman | 505 | 1228 | 1909 | 2.46 | 3.16 | 4.55 | 2.69 |
| Pakistan | 50093 | 101696 | 142554 | 2.66 | 2.69 | 3.08 | 2.02 |
| Philippines | 27904 | 54709 | 74810 | 3.04 | 2.51 | 2.49 | 1.53 |
| Qatar | 45 | 301 | 469 | 8.84 | 8.60 | 4.02 | 2.52 |
| Saudi Arabia | 4075 | 11240 | 18864 | 3.25 | 4.66 | 3.94 | 2.92 |
| Singapore | 1634 | 2572 | 2976 | 2.81 | 1.74 | 1.27 | 0.54 |
| Sri Lanka | 9889 | 16404 | 20843 | 2.43 | 1.67 | 2.03 | 1.20 |
| Syrian Arab Rep | 4561 | 10581 | 18102 | 3.10 | 3.46 | 3.69 | 2.82 |
| Thailand | 26867 | 51571 | 66115 | 3.02 | 2.58 | 2.09 | 1.44 |
| Turkey | 27509 | 49974 | 68466 | 2.49 | 2.50 | 2.33 | 1.67 |
| United Arab Emirates | 90 | 1312 | 1916 | 9.38 | 16.35 | 5.83 | 1.66 |
| Viet Nam | 33923 | 59451 | 78129 | 2.19 | 2.35 | 2.02 | 1.51 |
| Yemen | 4039 | 6547 | 9859 | 2.13 | 1.77 | 2.37 | 2.57 |
| Yemen, Dem | 1208 | 2124 | 3309 | 2.24 | 2.00 | 2.68 | 2.66 |
| **EUROPE** | **425129** | **492009** | **513110** | **0.91** | **0.64** | **0.33** | **0.18** |
| Albania | 1611 | 3050 | 4102 | 2.99 | 2.51 | 2.21 | 1.59 |
| Austria | 7048 | 7487 | 7498 | 0.58 | 0.20 | −0.05 | −0.08 |
| Belgium | 9153 | 9880 | 9925 | 0.67 | 0.33 | 0.04 | −0.02 |
| Bulgaria | 7867 | 9220 | 9713 | 0.83 | 0.48 | 0.47 | 0.26 |
| Czechoslovakia | 13654 | 15648 | 16776 | 0.73 | 0.60 | 0.43 | 0.53 |
| Denmark | 4581 | 5144 | 5126 | 0.76 | 0.52 | 0.08 | −0.18 |
| Finland | 4430 | 4875 | 4970 | 0.60 | 0.45 | 0.37 | −0.02 |
| France | 45684 | 54608 | 57083 | 1.30 | 0.79 | 0.30 | 0.16 |
| German Dem Rep | 17240 | 16642 | 16553 | −0.26 | −0.26 | −0.11 | −0.03 |
| Germany, Fed Rep | 55433 | 61106 | 59755 | 1.25 | 0.37 | −0.18 | −0.33 |
| Greece | 8327 | 9932 | 10734 | 0.53 | 0.57 | 0.59 | 0.41 |
| Hungary | 9984 | 10797 | 10908 | 0.33 | 0.36 | 0.16 | 0.10 |
| Ireland | 2834 | 3595 | 4247 | 0.29 | 1.64 | 1.11 | 1.04 |
| Italy | 50223 | 56874 | 58155 | 0.67 | 0.83 | 0.25 | 0.00 |
| Luxembourg | 314 | 363 | 358 | 1.11 | 1.32 | −0.12 | −0.19 |
| Malta | 329 | 382 | 419 | −0.55 | 1.19 | 0.68 | 0.53 |
| Netherlands | 11480 | 14506 | 15011 | 1.37 | 1.14 | 0.40 | 0.02 |
| Norway | 3581 | 4150 | 4227 | 0.78 | 0.66 | 0.27 | 0.03 |
| Poland | 29561 | 37556 | 41391 | 1.27 | 0.82 | 0.95 | 0.53 |
| Portugal | 8826 | 10077 | 10995 | 0.91 | 1.77 | 0.68 | 0.42 |
| Romania | 18407 | 23065 | 25629 | 0.67 | 0.85 | 0.76 | 0.60 |
| Spain | 30303 | 39019 | 43442 | 1.03 | 1.05 | 0.82 | 0.59 |
| Sweden | 7480 | 8278 | 8065 | 0.67 | 0.37 | 0.01 | −0.20 |
| Switzerland | 5362 | 6289 | 5889 | 1.77 | 0.44 | −0.26 | −0.56 |
| United Kingdom | 52559 | 55640 | 56235 | 0.73 | 0.20 | −0.01 | 0.01 |
| Yugoslavia | 18402 | 23191 | 25200 | 1.09 | 0.94 | 0.76 | 0.37 |
| **USSR** | **214335** | **278373** | **314818** | **1.49** | **0.95** | **0.95** | **0.69** |
| **OCEANIA** | **15762** | **24820** | **30403** | **2.08** | **1.85** | **1.50** | **1.19** |
| Australia | 10315 | 15714 | 18668 | 1.98 | 1.64 | 1.31 | 1.03 |
| Fiji | 394 | 684 | 821 | 3.27 | 2.03 | 1.66 | 0.79 |
| New Zealand | 2372 | 3291 | 3693 | 2.05 | 1.81 | 0.75 | 0.63 |
| Papua New Guinea | 1920 | 3696 | 5292 | 2.24 | 2.62 | 2.69 | 2.05 |
| Solomon Islands | 126 | 273 | X | 2.50 | 3.40 | 3.60 | X |
| **ANTARCTICA** | | | | | | | |

**Source:** U.N. Department of International Economic and Social Affairs.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 2.2 BIRTH, DEATHS, FERTILITY, AND MORTALITY, 1950–85

| | Estimated Crude Birth Rate (births per thousand population) | | Estimated Crude Death Rate (deaths per thousand population) | | Estimated Total Fertility Rate | | Estimated Life Expectancy at Birth | |
|---|---|---|---|---|---|---|---|---|
| | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1980–1985 average | Years Added Since 1950–1955 |
| **WORLD** | **35.9** | **27.3** | **16.4** | **10.6** | **4.92** | **3.55** | **64.6** | **14.7** |
| **AFRICA** | **48.3** | **46.4** | **23.3** | **16.5** | **6.54** | **6.43** | **49.7** | **12.2** |
| Algeria | 50.4 | 45.1 | 19.4 | 12.3 | 7.38 | 6.97 | 57.8 | 14.7 |
| Angola | 49.4 | 47.3 | 30.2 | 22.2 | 6.38 | 6.39 | 42.0 | 12.0 |
| Benin | 48.3 | 51.0 | 31.9 | 22.5 | 6.81 | 7.00 | 42.5 | 10.0 |
| Botswana | 52.6 | 50.0 | 19.6 | 12.7 | 6.42 | 6.50 | 54.5 | 12.0 |
| Burkina Faso | 50.2 | 47.8 | 30.3 | 22.2 | 6.50 | 6.50 | 42.0 | 12.0 |
| Burundi | 45.6 | 47.6 | 25.3 | 20.9 | 5.69 | 6.44 | 44.0 | 7.5 |
| Cameroon | 43.2 | 43.2 | 23.7 | 17.8 | 5.77 | 5.79 | 48.0 | 12.0 |
| Cape Verde | 44.8 | 23.9 | 16.9 | 10.3 | 6.09 | 2.64 | 57.0 | 13.5 |
| Central African Rep | 43.5 | 44.7 | 28.6 | 21.8 | 5.66 | 5.89 | 43.0 | 10.5 |
| Chad | 45.5 | 44.2 | 28.6 | 21.4 | 6.00 | 5.89 | 43.0 | 10.5 |
| Comoros | 48.2 | 46.3 | 21.2 | 15.9 | 6.32 | 6.29 | 50.0 | 10.0 |
| Congo | 45.2 | 44.5 | 24.7 | 18.6 | 5.87 | 5.99 | 46.5 | 10.5 |
| Djibouti | X | 47.0 | X | 20.5 | X | X | X | X |
| Egypt | 45.9 | 38.4 | 19.8 | 12.5 | 6.56 | 5.23 | 57.3 | 16.6 |
| Equatorial Guinea | 41.3 | 42.5 | 28.0 | 21.0 | 5.53 | 5.66 | 44.0 | 10.5 |
| Ethiopia | 50.2 | 49.2 | 27.0 | 21.5 | 6.66 | 6.70 | 42.9 | 10.0 |
| Gabon | 31.5 | 34.6 | 22.8 | 18.1 | 4.06 | 4.67 | 49.0 | 11.0 |
| Gambia | 47.2 | 48.4 | 33.0 | 29.0 | 6.36 | 6.39 | 35.0 | 4.4 |
| Ghana | 48.2 | 47.0 | 20.4 | 14.6 | 6.48 | 6.50 | 52.0 | 12.0 |
| Guinea | 48.2 | 46.8 | 31.4 | 23.5 | 6.39 | 6.19 | 40.2 | 9.5 |
| Guinea-Bissau | 41.4 | 40.7 | 27.4 | 21.7 | 5.06 | 5.38 | 43.0 | 9.5 |
| Ivory Coast | 43.2 | 46.0 | 24.7 | 18.0 | 6.61 | 6.70 | 47.0 | 11.0 |
| Kenya | 57.1 | 55.1 | 22.5 | 14.0 | 8.15 | 8.12 | 52.9 | 14.3 |
| Lesotho | 42.8 | 41.7 | 22.7 | 16.4 | 5.75 | 5.79 | 49.3 | 12.0 |
| Liberia | 45.8 | 48.7 | 22.9 | 17.2 | 6.27 | 6.90 | 49.0 | 11.5 |
| Libya | 49.0 | 45.6 | 18.3 | 10.9 | 7.17 | 7.17 | 57.9 | 15.0 |
| Madagascar | 43.8 | 44.4 | 22.0 | 16.5 | 5.79 | 6.09 | 49.6 | 11.9 |
| Malawi | 53.6 | 52.1 | 27.5 | 19.9 | 6.87 | 7.00 | 45.0 | 11.0 |
| Mali | 50.9 | 50.2 | 28.6 | 22.4 | 6.52 | 6.70 | 42.0 | 9.5 |
| Mauritania | 50.2 | 50.1 | 26.7 | 20.9 | 6.86 | 6.90 | 44.0 | 10.5 |
| Mauritius | 42.5 | 25.5 | 9.1 | 6.0 | 5.73 | 2.76 | 66.7 | 15.7 |
| Morocco | 50.1 | 44.0 | 19.6 | 11.5 | 7.15 | 6.44 | 57.9 | 15.0 |
| Mozambique | 44.8 | 44.1 | 22.6 | 16.5 | 5.70 | 6.09 | 49.4 | 12.0 |
| Niger | 45.8 | 51.0 | 29.5 | 22.9 | 7.06 | 7.10 | 42.5 | 9.5 |
| Nigeria | 51.6 | 50.4 | 23.6 | 17.1 | 6.87 | 7.10 | 48.5 | 12.0 |
| Rwanda | 51.2 | 51.1 | 21.6 | 16.6 | 6.83 | 7.30 | 49.5 | 9.5 |
| Senegal | 47.2 | 47.7 | 26.2 | 21.2 | 6.43 | 6.50 | 43.3 | 8.6 |
| Sierra Leone | 48.0 | 47.4 | 34.7 | 29.7 | 6.11 | 6.13 | 34.0 | 5.0 |
| Somalia | 46.5 | 46.5 | 26.7 | 21.3 | 6.11 | 6.09 | 42.9 | 10.0 |
| South Africa | 41.4 | 38.7 | 20.3 | 13.9 | 5.62 | 5.07 | 53.5 | 12.0 |
| Sudan | 47.0 | 45.9 | 24.8 | 17.4 | 6.68 | 6.58 | 47.7 | 10.5 |
| Swaziland | 48.3 | 47.5 | 24.4 | 17.2 | 6.41 | 6.50 | 48.6 | 12.9 |
| Tanzania, United Rep | 51.7 | 50.4 | 22.8 | 15.3 | 6.86 | 7.10 | 51.0 | 14.0 |
| Togo | 47.7 | 45.4 | 24.4 | 16.9 | 6.15 | 6.09 | 48.7 | 12.7 |
| Tunisia | 46.5 | 34.1 | 17.9 | 10.1 | 7.17 | 4.92 | 60.6 | 16.0 |
| Uganda | 48.7 | 49.9 | 20.1 | 14.7 | 6.91 | 6.90 | 52.0 | 12.0 |
| Zaire | 48.1 | 45.2 | 23.8 | 15.8 | 6.08 | 6.09 | 50.0 | 11.5 |
| Zambia | 49.4 | 48.1 | 21.4 | 15.1 | 6.62 | 6.76 | 51.3 | 13.5 |
| Zimbabwe | 46.7 | 47.2 | 18.0 | 12.3 | 6.61 | 6.60 | 55.7 | 14.2 |
| **NORTH AMERICA** | **28.2** | **21.6** | **10.0** | **6.6** | **4.11** | **2.69** | **71.1** | **6.7** |
| Barbados | 29.1 | 19.9 | 9.2 | 8.6 | 4.05 | 2.23 | 71.6 | 14.1 |
| Canada | 25.3 | 16.2 | 7.7 | 7.1 | 3.62 | 1.81 | 74.9 | 5.8 |
| Costa Rica | 45.3 | 30.5 | 9.1 | 4.2 | 6.95 | 3.50 | 73.0 | 15.7 |
| Cuba | 35.3 | 16.9 | 8.8 | 6.4 | 4.67 | 1.97 | 73.4 | 14.6 |
| Dominican Rep | 47.7 | 33.1 | 15.4 | 8.0 | 7.32 | 4.18 | 62.6 | 17.5 |
| El Salvador | 47.4 | 40.2 | 15.3 | 8.1 | 6.85 | 5.56 | 64.8 | 19.5 |
| Guatemala | 47.6 | 38.4 | 17.3 | 9.3 | 6.85 | 5.17 | 60.7 | 18.0 |
| Haiti | 44.4 | 41.3 | 21.6 | 14.2 | 6.15 | 5.74 | 52.7 | 15.1 |
| Honduras | 50.9 | 43.9 | 17.7 | 10.1 | 7.36 | 6.50 | 59.9 | 17.7 |
| Jamaica | 39.6 | 28.3 | 9.1 | 6.7 | 5.45 | 3.38 | 70.3 | 13.1 |
| Mexico | 44.9 | 33.9 | 11.3 | 7.1 | 6.74 | 4.61 | 65.7 | 15.0 |
| Nicaragua | 50.3 | 44.2 | 17.1 | 9.7 | 7.34 | 5.94 | 59.8 | 17.5 |
| Panama | 40.8 | 28.0 | 9.6 | 5.4 | 5.92 | 3.46 | 71.0 | 15.7 |
| Trinidad and Tobago | 36.3 | 24.6 | 7.3 | 6.2 | 5.02 | 2.90 | 70.1 | 12.2 |
| United States | 22.6 | 16.0 | 9.4 | 9.3 | 3.32 | 1.85 | 74.0 | 5.0 |
| **SOUTH AMERICA** | **39.7** | **30.9** | **12.2** | **8.5** | **5.80** | **4.00** | **64.0** | **11.7** |
| Argentina | 23.2 | 24.6 | 8.8 | 8.7 | 3.08 | 3.38 | 69.7 | 7.0 |
| Bolivia | 46.1 | 44.0 | 21.5 | 15.9 | 6.62 | 6.25 | 50.7 | 10.3 |
| Brazil | 42.1 | 30.6 | 12.3 | 8.4 | 6.15 | 3.81 | 63.4 | 12.4 |
| Chile | 35.7 | 24.8 | 11.9 | 7.7 | 5.02 | 2.90 | 67.0 | 12.9 |
| Colombia | 44.6 | 31.0 | 12.2 | 7.7 | 6.72 | 3.93 | 63.6 | 13.0 |
| Ecuador | 46.1 | 40.6 | 15.8 | 8.9 | 6.99 | 6.00 | 62.6 | 15.7 |
| Guyana | 40.4 | 28.5 | 8.6 | 5.9 | 6.01 | 3.26 | 68.2 | 13.0 |
| Paraguay | 42.2 | 36.0 | 11.9 | 7.2 | 6.62 | 4.85 | 65.1 | 13.2 |
| Peru | 46.3 | 36.7 | 17.6 | 10.7 | 6.87 | 5.00 | 58.6 | 14.7 |
| Suriname | 44.4 | 29.5 | 10.3 | 6.1 | 6.56 | 4.10 | 69.4 | 13.4 |
| Uruguay | 21.9 | 19.5 | 9.6 | 10.2 | 2.89 | 2.76 | 70.3 | 4.0 |
| Venezuela | 45.2 | 35.2 | 10.1 | 5.6 | 6.70 | 4.33 | 67.8 | 15.5 |

## Table 2.2

| | Estimated Crude Birth Rate (births per thousand population) | | Estimated Crude Death Rate (deaths per thousand population) | | Estimated Total Fertility Rate | | Estimated Life Expectancy at Birth | |
|---|---|---|---|---|---|---|---|---|
| | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1980–1985 average | Years Added Since 1950–1955 |
| **ASIA** | **40.7** | **27.4** | **19.4** | **10.2** | **5.67** | **3.56** | **57.9** | **16.7** |
| Afghanistan | 50.8 | 49.6 | 30.0 | 27.3 | 7.01 | 6.90 | 37.0 | 5.4 |
| Bahrain | 47.0 | 32.3 | 13.8 | 5.3 | 7.17 | 4.63 | 68.2 | 17.2 |
| Bangladesh | 46.7 | 44.8 | 22.0 | 17.5 | 6.68 | 6.15 | 47.8 | 7.4 |
| Bhutan | 42.2 | 38.4 | 24.1 | 18.1 | 5.92 | 5.53 | 45.9 | 9.6 |
| Burma | 42.8 | 37.9 | 19.9 | 12.7 | 5.84 | 5.33 | 55.0 | 15.0 |
| China | 37.2 | 18.5 | 19.7 | 6.8 | 5.38 | 2.33 | 67.4 | 26.8 |
| Cyprus | 25.2 | 19.7 | 10.5 | 8.2 | 3.42 | 2.31 | 74.3 | 7.3 |
| India | 47.1 | 33.2 | 22.2 | 13.3 | 6.51 | 4.41 | 52.5 | 13.8 |
| Indonesia | 42.9 | 30.7 | 21.5 | 13.0 | 5.42 | 3.89 | 52.5 | 15.0 |
| Iran | 51.8 | 40.5 | 17.7 | 10.4 | 8.13 | 5.64 | 60.2 | 14.1 |
| Iraq | 49.3 | 44.9 | 18.8 | 10.7 | 7.17 | 6.66 | 59.0 | 15.0 |
| Israel | 25.5 | 23.6 | 6.0 | 6.8 | 3.85 | 3.09 | 74.0 | 8.6 |
| Japan | 17.2 | 12.4 | 7.3 | 6.7 | 2.03 | 1.71 | 76.6 | 12.6 |
| Jordan | 48.0 | 44.9 | 18.7 | 8.4 | 7.17 | 7.38 | 64.2 | 21.0 |
| Kampuchea, Dem | 44.9 | 45.5 | 20.4 | 19.6 | 6.29 | 5.12 | 43.4 | 4.0 |
| Korea, Dem People's Rep | 39.5 | 30.5 | 12.2 | 7.4 | 5.57 | 4.00 | 64.6 | 17.1 |
| Korea, Rep | 39.6 | 21.0 | 12.5 | 6.3 | 5.37 | 2.46 | 67.5 | 20.0 |
| Kuwait | 44.5 | 36.8 | 9.0 | 3.5 | 7.38 | 6.15 | 71.2 | 15.4 |
| Lao People's Dem Rep | 42.2 | 40.6 | 18.5 | 15.5 | 5.68 | 5.84 | 49.7 | 9.3 |
| Lebanon | 42.7 | 29.3 | 13.3 | 8.8 | 6.35 | 3.79 | 65.0 | 9.0 |
| Malaysia | 43.2 | 29.2 | 13.3 | 6.4 | 6.69 | 3.69 | 66.9 | 18.4 |
| Mongolia | 41.2 | 33.8 | 13.4 | 7.2 | 5.72 | 4.82 | 64.6 | 19.6 |
| Nepal | 45.8 | 41.7 | 25.0 | 18.4 | 5.86 | 6.25 | 45.9 | 9.6 |
| Oman | 50.4 | 47.3 | 26.1 | 15.9 | 7.17 | 7.07 | 49.7 | 15.0 |
| Pakistan | 48.4 | 42.6 | 21.9 | 15.2 | 7.15 | 5.84 | 50.0 | 11.1 |
| Philippines | 43.6 | 32.3 | 13.1 | 6.9 | 6.57 | 4.20 | 64.5 | 17.0 |
| Qatar | 40.8 | 30.1 | 16.7 | 4.6 | 6.97 | 6.76 | 70.6 | 23.6 |
| Saudi Arabia | 48.9 | 43.0 | 21.3 | 12.1 | 7.26 | 7.07 | 56.0 | 17.0 |
| Singapore | 34.0 | 18.0 | 7.1 | 5.3 | 4.87 | 1.74 | 72.2 | 11.8 |
| Sri Lanka | 34.7 | 27.0 | 8.5 | 6.7 | 5.12 | 3.37 | 67.5 | 10.9 |
| Syrian Arab Rep | 47.4 | 46.5 | 16.6 | 7.2 | 7.46 | 7.17 | 67.0 | 21.0 |
| Thailand | 43.5 | 28.6 | 13.4 | 7.7 | 6.42 | 3.59 | 62.7 | 15.7 |
| Turkey | 41.0 | 32.5 | 15.0 | 9.0 | 6.01 | 4.45 | 63.0 | 16.0 |
| United Arab Emirates | 43.6 | 27.0 | 17.3 | 4.0 | 6.87 | 5.94 | 70.6 | 23.6 |
| Viet Nam | 41.1 | 31.2 | 19.5 | 10.1 | 5.64 | 4.30 | 58.8 | 18.4 |
| Yemen | 49.3 | 48.5 | 28.1 | 21.6 | 6.97 | 6.76 | 44.0 | 11.0 |
| Yemen, Dem | 50.3 | 47.6 | 27.9 | 18.8 | 6.97 | 6.87 | 46.5 | 13.5 |
| **EUROPE** | **18.7** | **14.0** | **10.2** | **10.7** | **2.59** | **1.90** | **73.2** | **7.9** |
| Albania | 39.9 | 27.7 | 10.1 | 5.8 | 5.74 | 3.60 | 70.9 | 15.7 |
| Austria | 18.5 | 12.1 | 12.5 | 12.6 | 2.79 | 1.63 | 73.0 | 7.3 |
| Belgium | 17.1 | 12.1 | 12.1 | 12.2 | 2.66 | 1.60 | 73.3 | 5.8 |
| Bulgaria | 16.9 | 15.4 | 8.2 | 10.7 | 2.19 | 2.25 | 72.3 | 8.2 |
| Czechoslovakia | 16.3 | 16.1 | 9.5 | 11.8 | 2.40 | 2.20 | 71.6 | 5.7 |
| Denmark | 17.0 | 11.1 | 9.7 | 10.9 | 2.59 | 1.52 | 74.9 | 3.9 |
| Finland | 18.1 | 12.7 | 9.3 | 10.3 | 2.58 | 1.60 | 73.2 | 6.9 |
| France | 18.0 | 13.8 | 11.2 | 10.7 | 2.85 | 1.83 | 74.5 | 8.0 |
| German Dem Rep | 17.4 | 12.5 | 13.3 | 13.7 | 2.45 | 1.65 | 72.7 | 5.6 |
| Germany, Fed Rep | 18.0 | 10.2 | 11.4 | 12.0 | 2.49 | 1.42 | 73.3 | 5.8 |
| Greece | 18.1 | 15.8 | 7.8 | 9.9 | 2.18 | 2.31 | 74.0 | 8.1 |
| Hungary | 13.6 | 14.3 | 10.1 | 12.7 | 1.83 | 2.06 | 71.2 | 7.2 |
| Ireland | 21.8 | 20.9 | 11.8 | 9.8 | 3.96 | 3.19 | 73.0 | 6.1 |
| Italy | 18.8 | 12.8 | 9.8 | 10.4 | 2.55 | 1.81 | 74.4 | 8.4 |
| Luxembourg | 16.0 | 10.1 | 11.9 | 11.9 | 2.36 | 1.38 | 72.8 | 6.9 |
| Malta | 22.6 | 17.3 | 8.8 | 10.5 | 3.11 | 1.97 | 71.7 | 5.8 |
| Netherlands | 20.9 | 11.6 | 7.8 | 8.7 | 3.14 | 1.44 | 75.9 | 3.8 |
| Norway | 17.4 | 12.3 | 9.5 | 10.5 | 2.90 | 1.69 | 75.9 | 3.2 |
| Poland | 20.1 | 18.5 | 7.6 | 9.0 | 2.66 | 2.25 | 72.0 | 10.7 |
| Portugal | 24.0 | 17.8 | 7.7 | 9.9 | 3.06 | 2.28 | 70.8 | 11.5 |
| Romania | 16.7 | 17.4 | 8.6 | 9.7 | 2.01 | 2.45 | 70.9 | 9.8 |
| Spain | 21.5 | 17.0 | 8.8 | 8.8 | 2.87 | 2.40 | 74.3 | 10.4 |
| Sweden | 14.5 | 10.5 | 10.0 | 11.6 | 2.34 | 1.55 | 75.8 | 4.0 |
| Switzerland | 18.5 | 8.0 | 9.5 | 10.7 | 2.52 | 1.33 | 75.9 | 6.7 |
| United Kingdom | 18.2 | 12.8 | 11.8 | 12.4 | 2.83 | 1.78 | 73.7 | 4.5 |
| Yugoslavia | 22.1 | 16.4 | 9.4 | 8.8 | 2.70 | 2.07 | 71.2 | 13.1 |
| **USSR** | **22.3** | **18.8** | **7.2** | **9.3** | **2.54** | **2.36** | **70.9** | **9.2** |
| **OCEANIA** | **26.7** | **21.1** | **10.5** | **8.4** | **3.69** | **2.71** | **67.6** | **6.6** |
| Australia | 21.9 | 16.2 | 8.7 | 7.7 | 3.28 | 2.00 | 74.4 | 4.8 |
| Fiji | 39.4 | 27.2 | 7.0 | 4.1 | 5.92 | 3.18 | 72.5 | 11.9 |
| New Zealand | 25.9 | 15.6 | 8.9 | 8.1 | 3.79 | 1.85 | 73.4 | 3.8 |
| Papua New Guinea | 43.7 | 40.4 | 21.3 | 13.6 | 6.25 | 5.99 | 53.3 | 18.2 |
| Solomon Islands | X | 47.0 | X | 11.0 | X | X | X | X |
| **ANTARCTICA** | | | | | | | | |

**Sources:** U.N. Department of International Economic and Social Affairs.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 2.3 AGE DISTRIBUTION, 1960–2000

| | Age Distribution (percent of total population) 0–14 | | | 15–64 | | | 65+ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1985 | 2000 | 1960 | 1985 | 2000 | 1960 | 1985 | 2000 |
| **WORLD** | **37.5** | **33.7** | **30.4** | **57.5** | **60.6** | **63.0** | **5.1** | **5.7** | **6.6** |
| **AFRICA** | **43.4** | **45.4** | **45.2** | **53.4** | **51.5** | **51.6** | **3.2** | **3.0** | **3.0** |
| Algeria | 43.8 | 45.9 | 43.2 | 52.4 | 50.6 | 53.5 | 3.9 | 3.5 | 3.3 |
| Angola | 41.8 | 44.6 | 45.2 | 55.4 | 52.4 | 51.8 | 2.8 | 3.0 | 3.0 |
| Benin | 40.7 | 46.5 | 47.5 | 52.0 | 50.7 | 49.9 | 7.2 | 2.8 | 2.6 |
| Botswana | 47.5 | 49.7 | 49.0 | 49.1 | 48.3 | 48.9 | 3.4 | 2.0 | 2.1 |
| Burkina Faso | 42.3 | 44.4 | 45.3 | 54.8 | 52.8 | 51.7 | 2.9 | 2.8 | 3.0 |
| Burundi | 40.4 | 44.3 | 44.4 | 56.6 | 52.4 | 52.3 | 3.0 | 3.3 | 3.3 |
| Cameroon | 40.3 | 42.9 | 42.9 | 56.5 | 53.2 | 53.3 | 3.1 | 3.9 | 3.7 |
| Cape Verde | 45.6 | 31.4 | 25.8 | 51.6 | 64.7 | 68.8 | 2.8 | 3.9 | 5.4 |
| Central African Rep | 38.5 | 42.5 | 43.4 | 57.3 | 53.7 | 53.0 | 4.1 | 3.8 | 3.6 |
| Chad | 39.6 | 42.3 | 43.2 | 56.7 | 54.1 | 53.2 | 3.7 | 3.6 | 3.5 |
| Comoros | 44.2 | 46.2 | 44.4 | 52.8 | 51.0 | 52.6 | 3.0 | 2.8 | 3.0 |
| Congo | 40.9 | 43.6 | 44.4 | 55.8 | 53.0 | 52.3 | 3.2 | 3.4 | 3.4 |
| Djibouti | X | X | X | X | X | X | X | X | X |
| Egypt | 40.6 | 39.4 | 35.9 | 55.1 | 56.2 | 59.4 | 4.3 | 4.4 | 4.7 |
| Equatorial Guinea | 37.5 | 41.4 | 42.2 | 57.6 | 54.4 | 53.8 | 4.9 | 4.2 | 3.9 |
| Ethiopia | 44.0 | 45.8 | 46.4 | 53.5 | 51.7 | 50.9 | 2.6 | 2.6 | 2.6 |
| Gabon | 32.4 | 35.5 | 40.6 | 61.7 | 58.5 | 53.8 | 5.9 | 6.1 | 5.6 |
| Gambia | 39.7 | 42.5 | 43.5 | 56.7 | 54.5 | 53.4 | 3.6 | 3.1 | 3.1 |
| Ghana | 44.6 | 46.5 | 46.0 | 53.0 | 50.6 | 51.1 | 2.5 | 2.8 | 2.9 |
| Guinea | 41.5 | 43.1 | 43.9 | 54.2 | 54.0 | 53.0 | 4.3 | 2.9 | 3.1 |
| Guinea-Bissau | 37.4 | 40.7 | 41.4 | 59.1 | 55.0 | 54.4 | 3.5 | 4.3 | 4.1 |
| Ivory Coast | 40.9 | 45.1 | 45.5 | 54.4 | 52.0 | 51.5 | 4.7 | 2.9 | 3.0 |
| Kenya | 49.7 | 52.5 | 51.9 | 47.7 | 45.7 | 46.3 | 2.6 | 1.8 | 1.8 |
| Lesotho | 40.5 | 42.3 | 42.2 | 55.6 | 54.1 | 54.1 | 4.0 | 3.6 | 3.7 |
| Liberia | 42.4 | 46.8 | 47.0 | 54.4 | 50.2 | 50.1 | 3.2 | 3.0 | 2.9 |
| Libya | 43.3 | 46.5 | 44.7 | 52.7 | 51.2 | 52.5 | 4.0 | 2.3 | 2.8 |
| Madagascar | 41.1 | 44.2 | 44.8 | 55.9 | 52.4 | 51.8 | 3.0 | 3.4 | 3.4 |
| Malawi | 45.7 | 48.1 | 48.7 | 51.7 | 49.6 | 49.0 | 2.6 | 2.4 | 2.4 |
| Mali | 43.4 | 46.1 | 45.7 | 54.0 | 51.2 | 51.5 | 2.6 | 2.7 | 2.8 |
| Mauritania | 43.6 | 46.4 | 46.9 | 53.7 | 50.8 | 50.3 | 2.7 | 2.8 | 2.7 |
| Mauritius | 46.6 | 31.6 | 26.2 | 50.9 | 64.9 | 68.4 | 2.5 | 3.5 | 5.3 |
| Morocco | 44.8 | 45.6 | 40.7 | 52.6 | 51.4 | 55.9 | 2.6 | 3.0 | 3.4 |
| Mozambique | 40.8 | 44.8 | 44.4 | 56.2 | 51.8 | 52.2 | 3.0 | 3.4 | 3.4 |
| Niger | 41.5 | 46.7 | 47.7 | 52.8 | 50.0 | 49.8 | 5.7 | 3.3 | 2.5 |
| Nigeria | 45.4 | 48.3 | 48.9 | 52.3 | 49.3 | 48.6 | 2.3 | 2.4 | 2.4 |
| Rwanda | 44.6 | 48.8 | 49.5 | 53.0 | 48.8 | 48.0 | 2.5 | 2.5 | 2.5 |
| Senegal | 42.6 | 45.0 | 45.6 | 54.4 | 52.1 | 51.4 | 3.0 | 2.9 | 2.9 |
| Sierra Leone | 40.2 | 41.4 | 42.1 | 56.6 | 55.6 | 54.7 | 3.2 | 3.0 | 3.2 |
| Somalia | 41.5 | 43.7 | 44.8 | 55.4 | 52.3 | 51.4 | 3.0 | 4.0 | 3.8 |
| South Africa | 40.1 | 41.0 | 40.0 | 55.0 | 54.9 | 55.9 | 4.9 | 4.0 | 4.1 |
| Sudan | 44.3 | 45.1 | 43.5 | 52.7 | 52.1 | 53.5 | 2.9 | 2.8 | 3.1 |
| Swaziland | 43.2 | 46.0 | 46.2 | 53.9 | 51.0 | 50.8 | 2.8 | 3.0 | 3.0 |
| Tanzania, United Rep | 46.0 | 48.8 | 49.4 | 51.2 | 48.9 | 48.3 | 2.9 | 2.3 | 2.4 |
| Togo | 42.4 | 44.5 | 45.3 | 54.0 | 52.3 | 51.6 | 3.6 | 3.2 | 3.1 |
| Tunisia | 43.4 | 39.6 | 33.0 | 52.5 | 56.1 | 62.1 | 4.2 | 4.3 | 4.9 |
| Uganda | 46.6 | 48.5 | 48.2 | 50.8 | 49.0 | 49.2 | 2.6 | 2.5 | 2.5 |
| Zaire | 44.1 | 45.1 | 45.3 | 52.8 | 52.0 | 51.7 | 3.1 | 2.9 | 3.0 |
| Zambia | 45.2 | 47.3 | 47.9 | 52.4 | 50.0 | 49.4 | 2.4 | 2.7 | 2.7 |
| Zimbabwe | 45.5 | 47.6 | 48.1 | 51.8 | 49.6 | 49.2 | 2.7 | 2.7 | 2.7 |
| **NORTH AMERICA** | **34.6** | **28.3** | **26.7** | **57.8** | **62.9** | **64.4** | **7.7** | **8.8** | **8.9** |
| Barbados | 36.1 | 27.6 | 24.7 | 55.2 | 63.0 | 66.9 | 6.7 | 9.3 | 8.3 |
| Canada | 33.5 | 22.5 | 20.5 | 59.0 | 67.9 | 67.8 | 7.5 | 9.6 | 11.8 |
| Costa Rica | 47.5 | 36.7 | 32.5 | 49.5 | 59.5 | 62.5 | 3.0 | 3.8 | 4.9 |
| Cuba | 34.4 | 26.4 | 24.1 | 60.8 | 65.7 | 66.9 | 4.8 | 7.9 | 8.9 |
| Dominican Rep | 46.8 | 40.7 | 33.6 | 48.9 | 56.3 | 62.3 | 4.3 | 3.0 | 4.1 |
| El Salvador | 45.1 | 44.6 | 40.7 | 52.0 | 52.0 | 55.5 | 2.9 | 3.4 | 3.8 |
| Guatemala | 46.2 | 43.1 | 39.5 | 51.1 | 53.9 | 56.7 | 2.7 | 3.0 | 3.8 |
| Haiti | 40.9 | 43.6 | 43.4 | 55.1 | 53.0 | 53.5 | 3.9 | 3.4 | 3.1 |
| Honduras | 45.6 | 46.9 | 42.3 | 52.2 | 50.2 | 54.4 | 2.1 | 2.9 | 3.3 |
| Jamaica | 41.7 | 36.8 | 29.9 | 54.0 | 57.4 | 64.5 | 4.3 | 5.9 | 5.6 |
| Mexico | 45.6 | 42.2 | 34.1 | 51.0 | 54.3 | 61.7 | 3.4 | 3.5 | 4.2 |
| Nicaragua | 48.0 | 46.7 | 42.7 | 49.7 | 50.7 | 54.2 | 2.3 | 2.5 | 3.1 |
| Panama | 43.5 | 37.5 | 31.5 | 52.5 | 58.0 | 63.1 | 4.0 | 4.5 | 5.4 |
| Trinidad and Tobago | 43.0 | 31.6 | 27.6 | 53.0 | 62.6 | 65.0 | 4.0 | 5.8 | 7.4 |
| United States | 31.0 | 21.9 | 21.7 | 59.7 | 66.7 | 66.6 | 9.2 | 11.5 | 11.7 |
| **SOUTH AMERICA** | **41.8** | **36.7** | **32.7** | **54.7** | **58.6** | **61.8** | **3.5** | **4.7** | **5.5** |
| Argentina | 30.8 | 31.0 | 28.5 | 63.7 | 60.5 | 61.9 | 5.5 | 8.5 | 9.6 |
| Bolivia | 42.9 | 43.8 | 43.5 | 54.0 | 53.0 | 53.2 | 3.2 | 3.2 | 3.2 |
| Brazil | 43.6 | 36.4 | 31.8 | 53.5 | 59.3 | 62.8 | 2.9 | 4.3 | 5.4 |
| Chile | 39.1 | 31.2 | 28.0 | 56.5 | 63.1 | 65.2 | 4.3 | 5.7 | 6.7 |
| Colombia | 46.3 | 37.2 | 32.7 | 50.6 | 59.1 | 62.8 | 3.1 | 3.8 | 4.5 |
| Ecuador | 44.4 | 44.2 | 41.3 | 52.0 | 52.4 | 55.2 | 3.6 | 3.4 | 3.5 |
| Guyana | 48.5 | 37.0 | 28.2 | 48.2 | 59.1 | 66.9 | 3.3 | 3.9 | 4.9 |
| Paraguay | 46.0 | 41.7 | 37.7 | 50.7 | 54.8 | 58.5 | 3.3 | 3.6 | 3.7 |
| Peru | 43.3 | 40.5 | 35.6 | 53.2 | 55.9 | 60.1 | 3.4 | 3.6 | 4.3 |
| Suriname | 47.6 | 42.6 | 36.3 | 48.3 | 53.0 | 59.1 | 4.1 | 4.5 | 4.6 |
| Uruguay | 27.9 | 26.9 | 25.0 | 64.0 | 62.4 | 62.9 | 8.1 | 10.7 | 12.2 |
| Venezuela | 46.2 | 41.0 | 35.7 | 51.3 | 56.0 | 60.5 | 2.5 | 2.9 | 3.8 |

# Table 2.3

## Age Distribution (percent of total population)

| | 0–14 | | | 15–64 | | | 65+ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1985 | 2000 | 1960 | 1985 | 2000 | 1960 | 1985 | 2000 |
| **ASIA** | **40.4** | **35.0** | **29.2** | **55.8** | **60.6** | **65.1** | **3.7** | **4.4** | **5.7** |
| Afghanistan | 42.9 | 43.3 | 43.1 | 54.6 | 54.2 | 54.4 | 2.6 | 2.4 | 2.5 |
| Bahrain | 43.1 | 33.3 | 29.9 | 54.2 | 64.7 | 67.8 | 2.7 | 2.0 | 2.3 |
| Bangladesh | 40.8 | 45.7 | 40.4 | 55.1 | 51.2 | 56.7 | 4.0 | 3.1 | 2.8 |
| Bhutan | 40.2 | 40.0 | 37.1 | 56.6 | 56.6 | 59.1 | 3.2 | 3.3 | 3.7 |
| Burma | 39.1 | 41.3 | 37.1 | 57.5 | 55.0 | 58.7 | 3.4 | 3.7 | 4.2 |
| China | 40.1 | 30.7 | 24.0 | 56.6 | 64.1 | 69.2 | 3.3 | 5.2 | 6.8 |
| Cyprus | 36.7 | 24.9 | 23.0 | 57.4 | 65.0 | 66.9 | 5.9 | 10.1 | 10.1 |
| India | 41.3 | 37.3 | 30.7 | 54.6 | 59.2 | 64.5 | 4.1 | 3.5 | 4.8 |
| Indonesia | 40.2 | 38.5 | 29.8 | 56.5 | 58.1 | 65.6 | 3.3 | 3.4 | 4.6 |
| Iran | 47.1 | 43.1 | 36.9 | 50.8 | 53.5 | 59.5 | 2.1 | 3.4 | 3.6 |
| Iraq | 46.1 | 46.4 | 41.9 | 51.4 | 50.9 | 55.0 | 2.4 | 2.7 | 3.1 |
| Israel | 36.1 | 32.8 | 27.2 | 59.1 | 59.0 | 64.3 | 4.9 | 8.2 | 8.4 |
| Japan | 30.2 | 21.5 | 17.5 | 64.1 | 68.6 | 67.6 | 5.7 | 9.9 | 14.9 |
| Jordan | 44.4 | 47.8 | 48.8 | 51.5 | 49.4 | 48.5 | 4.1 | 2.8 | 2.7 |
| Kampuchea, Dem | 42.5 | 32.6 | 36.8 | 54.8 | 64.7 | 59.6 | 2.7 | 2.6 | 3.6 |
| Korea, Dem People's Rep | 43.7 | 38.1 | 33.0 | 53.0 | 58.1 | 62.5 | 3.3 | 3.8 | 4.5 |
| Korea, Rep | 41.9 | 29.7 | 25.3 | 54.7 | 65.9 | 68.2 | 3.3 | 4.4 | 6.5 |
| Kuwait | 34.8 | 41.1 | 36.8 | 62.9 | 57.4 | 60.3 | 2.2 | 1.5 | 2.9 |
| Lao People's Dem Rep | 41.3 | 42.8 | 38.4 | 56.4 | 54.1 | 58.1 | 2.3 | 3.1 | 3.5 |
| Lebanon | 40.8 | 37.5 | 33.7 | 53.4 | 57.4 | 60.5 | 5.8 | 5.1 | 5.8 |
| Malaysia | 44.9 | 36.7 | 30.8 | 50.9 | 59.5 | 64.6 | 4.2 | 3.9 | 4.5 |
| Mongolia | 41.6 | 41.0 | 35.0 | 54.3 | 55.6 | 60.8 | 4.0 | 3.3 | 4.2 |
| Nepal | 38.4 | 43.3 | 39.6 | 57.7 | 53.8 | 57.0 | 3.9 | 2.9 | 3.5 |
| Oman | 43.3 | 44.2 | 43.3 | 54.0 | 53.4 | 53.9 | 2.7 | 2.5 | 2.8 |
| Pakistan | 43.7 | 44.2 | 39.2 | 51.8 | 53.0 | 57.9 | 4.4 | 2.8 | 3.0 |
| Philippines | 46.9 | 38.6 | 32.9 | 49.5 | 58.3 | 63.0 | 3.6 | 3.1 | 4.1 |
| Qatar | 39.0 | 33.8 | 37.1 | 58.3 | 63.6 | 58.7 | 2.7 | 2.6 | 4.3 |
| Saudi Arabia | 43.3 | 43.1 | 42.6 | 53.4 | 54.1 | 54.5 | 3.3 | 2.7 | 2.9 |
| Singapore | 43.2 | 24.8 | 21.4 | 54.7 | 70.1 | 71.6 | 2.1 | 5.1 | 7.0 |
| Sri Lanka | 42.1 | 34.2 | 28.3 | 54.3 | 61.4 | 65.7 | 3.6 | 4.4 | 5.9 |
| Syrian Arab Rep | 44.4 | 47.5 | 45.7 | 51.8 | 49.3 | 51.3 | 3.8 | 3.2 | 3.0 |
| Thailand | 45.6 | 36.7 | 29.4 | 51.0 | 60.0 | 66.1 | 3.3 | 3.3 | 4.5 |
| Turkey | 41.2 | 37.1 | 33.8 | 55.2 | 58.6 | 60.9 | 3.5 | 4.2 | 5.4 |
| United Arab Emirates | 43.7 | 30.7 | 27.6 | 53.0 | 66.8 | 68.6 | 3.4 | 2.4 | 3.8 |
| Viet Nam | 39.7 | 40.2 | 32.3 | 56.4 | 55.9 | 63.0 | 3.8 | 3.9 | 4.7 |
| Yemen | 42.4 | 45.3 | 44.6 | 54.4 | 51.4 | 51.9 | 3.2 | 3.3 | 3.5 |
| Yemen, Dem | 44.8 | 45.2 | 44.5 | 52.4 | 52.1 | 52.6 | 2.9 | 2.7 | 2.9 |
| **EUROPE** | **25.8** | **20.9** | **19.3** | **64.5** | **66.6** | **66.1** | **9.7** | **12.4** | **14.5** |
| Albania | 41.1 | 35.4 | 31.3 | 53.7 | 59.7 | 62.8 | 5.2 | 4.9 | 5.9 |
| Austria | 22.1 | 18.3 | 17.8 | 65.8 | 67.5 | 67.0 | 12.0 | 14.2 | 15.2 |
| Belgium | 23.5 | 18.7 | 17.1 | 64.5 | 68.0 | 67.0 | 12.0 | 13.3 | 15.9 |
| Bulgaria | 26.1 | 22.3 | 20.6 | 66.4 | 66.3 | 63.9 | 7.5 | 11.4 | 15.5 |
| Czechoslovakia | 27.4 | 24.5 | 21.7 | 64.0 | 64.4 | 66.0 | 8.6 | 11.1 | 12.3 |
| Denmark | 25.2 | 18.8 | 16.0 | 64.2 | 66.4 | 68.6 | 10.6 | 14.8 | 15.4 |
| Finland | 30.4 | 19.0 | 16.9 | 62.4 | 68.7 | 68.9 | 7.2 | 12.3 | 14.1 |
| France | 26.4 | 20.9 | 19.0 | 62.0 | 66.7 | 66.2 | 11.6 | 12.4 | 14.8 |
| German Dem Rep | 21.1 | 18.5 | 17.4 | 65.2 | 67.5 | 68.0 | 13.7 | 14.0 | 14.6 |
| Germany, Fed Rep | 21.3 | 15.7 | 15.9 | 67.8 | 70.3 | 67.6 | 10.8 | 14.0 | 16.5 |
| Greece | 26.5 | 21.9 | 21.9 | 65.3 | 64.8 | 62.3 | 8.3 | 13.3 | 15.6 |
| Hungary | 25.3 | 21.8 | 18.7 | 65.6 | 65.8 | 66.6 | 9.0 | 12.3 | 14.7 |
| Ireland | 31.1 | 30.5 | 26.9 | 57.7 | 58.6 | 63.8 | 11.2 | 10.9 | 9.4 |
| Italy | 24.9 | 19.9 | 18.0 | 65.8 | 66.7 | 65.8 | 9.3 | 13.4 | 16.2 |
| Luxembourg | 21.3 | 17.5 | 15.8 | 67.8 | 69.1 | 68.5 | 10.8 | 13.5 | 15.7 |
| Malta | 36.8 | 23.9 | 21.3 | 55.9 | 67.1 | 68.6 | 7.3 | 9.0 | 9.9 |
| Netherlands | 30.0 | 19.0 | 16.3 | 61.0 | 69.0 | 69.6 | 9.0 | 11.9 | 14.1 |
| Norway | 25.9 | 20.1 | 17.2 | 63.0 | 64.5 | 67.5 | 11.1 | 15.5 | 15.3 |
| Poland | 33.5 | 25.0 | 21.6 | 60.8 | 65.6 | 66.1 | 5.8 | 9.4 | 12.3 |
| Portugal | 29.2 | 24.8 | 22.2 | 62.9 | 64.7 | 65.9 | 8.0 | 10.4 | 11.9 |
| Romania | 28.2 | 25.1 | 23.1 | 65.1 | 65.4 | 64.1 | 6.7 | 9.6 | 12.8 |
| Spain | 27.4 | 24.6 | 22.7 | 64.4 | 64.3 | 63.9 | 8.2 | 11.1 | 13.5 |
| Sweden | 22.0 | 17.8 | 15.5 | 66.0 | 65.2 | 67.3 | 12.0 | 17.0 | 17.2 |
| Switzerland | 23.6 | 15.7 | 12.0 | 66.3 | 68.6 | 67.4 | 10.1 | 15.7 | 20.6 |
| United Kingdom | 23.3 | 19.3 | 19.1 | 65.1 | 66.0 | 66.0 | 11.7 | 14.7 | 14.9 |
| Yugoslavia | 30.5 | 23.4 | 20.3 | 63.2 | 68.1 | 66.9 | 6.3 | 8.4 | 12.9 |
| **USSR** | **30.7** | **24.8** | **23.6** | **62.6** | **65.9** | **64.5** | **6.8** | **9.3** | **11.9** |
| **OCEANIA** | **32.9** | **28.4** | **26.1** | **59.6** | **63.4** | **64.8** | **7.4** | **8.2** | **9.1** |
| Australia | 30.1 | 24.2 | 22.0 | 61.4 | 66.1 | 67.0 | 8.5 | 9.7 | 11.0 |
| Fiji | 48.0 | 35.5 | 30.1 | 49.5 | 60.9 | 64.9 | 2.5 | 3.5 | 5.0 |
| New Zealand | 32.9 | 24.7 | 22.3 | 58.5 | 65.7 | 67.3 | 8.6 | 9.6 | 10.5 |
| Papua New Guinea | 40.5 | 42.6 | 38.5 | 56.6 | 54.1 | 57.8 | 2.9 | 3.3 | 3.7 |
| Solomon Islands | X | X | X | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | | | | |

**Source:** U.N. Department of International Economic and Social Affairs.
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

# Table 2.4 HEALTH INDICATORS, 1960–85

| | Estimated Infant Mortality (per thousand live births) | | Minimum Daily Calorie Requirement | Daily Calorie Supply as Percentage of Requirement | | | Percentage of Married Couples of Childbearing Age Using Contraception | |
|---|---|---|---|---|---|---|---|---|
| | 1960–65 | 1980–85 | | 1964–66 | 1974–76 | 1980–82 | 1970 | 1982 |
| **WORLD** | 117 | 81 | | | | | | |
| **AFRICA** | 157 | 114 | | | | | | |
| Algeria | 160 | 109 | 2400 | 77 | 90 | 110 | X | 7 |
| Angola | 200 | 149 | 2350 | 81 | 88 | 99 | X | X |
| Benin | 200 | 149 | 2300 | 92 | 87 | 94 | X | 18 |
| Botswana | 111 | 79 | 2320 | 85 | 90 | 106 | X | X |
| Burkina Faso | 200 | 149 | 2370 | 86 | 83 | 81 | X | 1 |
| Burundi | 172 | 137 | 2330 | 96 | 96 | 102 | X | 1 |
| Cameroon | 160 | 117 | 2320 | 87 | 102 | 93 | X | 11 |
| Cape Verde | 115 | 77 | 2350 | 76 | 94 | 116 | X | X |
| Central African Rep | 189 | 143 | 2260 | 94 | 99 | 95 | X | X |
| Chad | 189 | 143 | 2380 | 100 | 74 | 75 | X | 1 |
| Comoros | 128 | 88 | 2340 | 95 | 95 | 98 | X | X |
| Congo | 166 | 124 | 2220 | 102 | 102 | 111 | X | X |
| Djibouti | X | X | X | X | X | X | X | X |
| Egypt | 160 | 113 | 2510 | 103 | 112 | 130 | X | 24 |
| Equatorial Guinea | 183 | 137 | X | X | X | X | X | X |
| Ethiopia | 170 | 143 | 2330 | 90 | 79 | 95 | X | 2 |
| Gabon | 151 | 112 | 2340 | 88 | 104 | 119 | X | X |
| Gambia | 220 | 193 | 2380 | 99 | 90 | 93 | X | X |
| Ghana | 137 | 98 | 2300 | 87 | 94 | 72 | X | 10 |
| Guinea | 202 | 159 | 2310 | 89 | 89 | 81 | X | 1 |
| Guinea-Bissau | 183 | 143 | 2310 | 86 | 94 | 97 | X | X |
| Ivory Coast | 166 | 122 | 2310 | 110 | 102 | 115 | X | 3 |
| Kenya | 130 | 82 | 2320 | 97 | 94 | 88 | 6 | 8 |
| Lesotho | 141 | 110 | 2280 | 90 | 90 | 103 | X | 5 |
| Liberia | 154 | 112 | 2310 | 104 | 95 | 98 | X | X |
| Libya | 150 | 92 | 2360 | 84 | 147 | 160 | X | X |
| Madagascar | 104 | 67 | 2270 | 106 | 111 | 111 | X | X |
| Malawi | 205 | 165 | 2320 | 91 | 98 | 96 | X | 1 |
| Mali | 189 | 149 | 2350 | 88 | 83 | 74 | X | 1 |
| Mauritania | 176 | 137 | 2310 | 89 | 78 | 95 | X | 1 |
| Mauritius | 61 | 32 | 2270 | 105 | 111 | 124 | X | X |
| Morocco | 154 | 99 | 2420 | 94 | 107 | 109 | X | 26 |
| Mozambique | 154 | 110 | 2340 | 86 | 85 | 80 | X | 1 |
| Niger | 186 | 140 | 2350 | 91 | 84 | 105 | X | 1 |
| Nigeria | 157 | 114 | 2360 | 95 | 94 | 104 | X | 6 |
| Rwanda | 143 | 110 | 2320 | 75 | 88 | 91 | X | 1 |
| Senegal | 177 | 141 | 2380 | 101 | 94 | 99 | X | 4 |
| Sierra Leone | 232 | 200 | 2300 | 88 | 85 | 84 | X | 4 |
| Somalia | 170 | 143 | 2310 | 91 | 91 | 90 | X | 1 |
| South Africa | 129 | 92 | 2450 | 111 | 119 | 117 | X | X |
| Sudan | 165 | 118 | 2350 | 79 | 91 | 99 | X | 5 |
| Swaziland | 150 | 129 | 2320 | 87 | 106 | 109 | X | X |
| Tanzania, United Rep | 145 | 98 | 2320 | 85 | 90 | 105 | X | 1 |
| Togo | 170 | 113 | 2300 | 97 | 89 | 94 | X | X |
| Tunisia | 152 | 85 | 2390 | 94 | 110 | 115 | X | 41 |
| Uganda | 132 | 94 | 2330 | 95 | 88 | 76 | X | 1 |
| Zaire | 146 | 107 | 2220 | 97 | 102 | 96 | X | 3 |
| Zambia | 144 | 101 | 2310 | 89 | 99 | 90 | X | 1 |
| Zimbabwe | 111 | 70 | 2390 | 88 | 89 | 91 | X | 22 |
| **NORTH AMERICA** | 43 | 27 | | | | | | |
| Barbados | 61 | 23 | 2420 | 108 | 120 | 127 | X | X |
| Canada | 26 | 11 | 2660 | 120 | 125 | 129 | X | X |
| Costa Rica | 81 | 20 | 2240 | 104 | 114 | 118 | X | 65 |
| Cuba | 60 | 20 | 2310 | 102 | 116 | 126 | X | 79 |
| Dominican Rep | 110 | 64 | 2260 | 83 | 93 | 95 | X | 46 |
| El Salvador | 128 | 71 | 2290 | 80 | 90 | 92 | X | 34 |
| Guatemala | 115 | 68 | 2190 | 92 | 95 | 96 | X | 18 |
| Haiti | 170 | 108 | 2260 | 88 | 86 | 84 | X | 20 |
| Honduras | 137 | 82 | 2260 | 87 | 92 | 96 | X | 27 |
| Jamaica | 54 | 28 | 2240 | 98 | 116 | 113 | X | 51 |
| Mexico | 86 | 53 | 2330 | 111 | 117 | 126 | X | 39 |
| Nicaragua | 136 | 85 | 2250 | 111 | 109 | 100 | X | 9 |
| Panama | 63 | 26 | 2310 | 99 | 104 | 103 | X | 61 |
| Trinidad and Tobago | 48 | 28 | 2420 | 95 | 102 | 121 | 44 | 52 |
| United States | 25 | 12 | 2640 | 127 | 133 | 138 | 65 | 76 |
| **SOUTH AMERICA** | 101 | 64 | | | | | | |
| Argentina | 60 | 36 | 2650 | 121 | 127 | 127 | X | X |
| Bolivia | 164 | 124 | 2390 | 77 | 84 | 89 | X | 24 |
| Brazil | 109 | X | 2390 | 102 | 104 | 108 | X | 50 |
| Chile | 111 | 40 | 2440 | 109 | 108 | 111 | X | 43 |
| Colombia | 85 | 53 | 2320 | 93 | 100 | 109 | X | 55 |
| Ecuador | 132 | 77 | 2290 | 84 | 91 | 91 | X | 40 |
| Guyana | 62 | 35 | 2270 | 105 | 104 | 103 | X | X |
| Paraguay | 81 | 45 | 2310 | 113 | 118 | 123 | X | 35 |
| Peru | 136 | 99 | 2350 | 96 | 95 | 91 | X | 41 |
| Suriname | 63 | 31 | 2260 | 104 | 108 | 111 | X | X |
| Uruguay | 48 | 38 | 2670 | 105 | 111 | 105 | X | X |
| Venezuela | 77 | 39 | 2470 | 92 | 95 | 104 | X | 49 |

# Table 2.4

| | Estimated Infant Mortality (per thousand live births) 1960–65 | 1980–85 | Minimum Daily Calorie Requirement | Daily Calorie Supply as Percentage of Requirement 1964–66 | 1974–76 | 1980–82 | Percentage of Married Couples of Childbearing Age Using Contraception 1970 | 1982 |
|---|---|---|---|---|---|---|---|---|
| **ASIA** | **133** | **87** | | | | | | |
| Afghanistan | 228 | 205 | 2440 | 92 | 88 | 84 | 2 | X |
| Bahrain | 110 | 37 | X | X | X | X | X | X |
| Bangladesh | 156 | 133 | 2210 | 90 | 83 | 83 | X | 25 |
| Bhutan | 189 | 144 | 2310 | X | X | X | X | X |
| Burma | 150 | 94 | 2160 | 92 | 102 | 109 | X | 5 |
| China | 115 | 38 | 2360 | 86 | 93 | 106 | X | 71 |
| Cyprus | 29 | 17 | 2480 | 107 | 122 | 138 | X | X |
| India | 157 | 118 | 2210 | 89 | 87 | 92 | 12 | 32 |
| Indonesia | 145 | 87 | 2160 | 82 | 95 | 109 | X | 58 |
| Iran | 156 | 101 | 2410 | 92 | 117 | 120 | X | 23 |
| Iraq | 130 | 72 | 2410 | 91 | 103 | 116 | 14 | X |
| Israel | 29 | 15 | 2570 | 110 | 120 | 118 | X | X |
| Japan | 24 | 8 | 2340 | 113 | 119 | 122 | 56 | 56 |
| Jordan | 126 | 63 | 2460 | 95 | 87 | 105 | 22 | 26 |
| Kampuchea, Dem | 140 | 160 | 2220 | 97 | 84 | 89 | X | X |
| Korea, Dem People's Rep | 71 | 32 | 2340 | 97 | 116 | 131 | X | X |
| Korea, Rep | 71 | 29 | 2350 | 96 | 117 | 125 | 25 | 58 |
| Kuwait | 77 | 30 | X | X | X | X | X | X |
| Lao People's Dem Rep | 150 | 122 | 2220 | 87 | 84 | 89 | X | X |
| Lebanon | 62 | 48 | 2480 | 100 | 104 | 120 | 53 | X |
| Malaysia | 63 | 29 | 2240 | 62 | 111 | 118 | 33 | 42 |
| Mongolia | 97 | 50 | 2430 | 106 | 105 | 113 | X | X |
| Nepal | 189 | 144 | 2200 | 91 | 91 | 91 | X | 7 |
| Oman | 184 | 122 | X | X | X | X | X | X |
| Pakistan | 153 | 120 | 2310 | 77 | 89 | 97 | 6 | 14 |
| Philippines | 97 | 50 | 2260 | 82 | 94 | 106 | 15 | 48 |
| Qatar | 120 | 45 | X | X | X | X | X | X |
| Saudi Arabia | 174 | 103 | 2420 | 80 | 83 | 123 | X | X |
| Singapore | 30 | 11 | 2300 | 111 | 130 | 128 | 60 | 71 |
| Sri Lanka | 65 | 38 | 2220 | 100 | 92 | 98 | X | 55 |
| Syrian Arab Rep | 124 | 57 | 2480 | 90 | 103 | 125 | X | 23 |
| Thailand | 95 | 51 | 2220 | 94 | 100 | 104 | 15 | 59 |
| Turkey | 176 | 110 | 2520 | 105 | 116 | 121 | 32 | 38 |
| United Arab Emirates | 120 | 45 | X | X | X | X | X | X |
| Viet Nam | 150 | 90 | 2160 | 93 | 95 | 93 | X | 21 |
| Yemen | 205 | 154 | 2420 | 93 | 92 | 104 | X | 1 |
| Yemen, Dem | 202 | 138 | 2410 | 84 | 80 | 94 | X | X |
| **EUROPE** | **37** | **16** | | | | | | |
| Albania | 95 | 43 | 2410 | 101 | 113 | 121 | X | X |
| Austria | 32 | 13 | 2630 | 125 | 126 | 133 | X | X |
| Belgium | 27 | 11 | 2640 | 133 | 139 | 140 | X | X |
| Bulgaria | 36 | 20 | 2500 | 137 | 141 | 147 | X | 76 |
| Czechoslovakia | 23 | 16 | 2470 | 138 | 138 | 142 | X | 95 |
| Denmark | 20 | 8 | 2690 | 126 | 125 | 139 | 67 | X |
| Finland | 19 | 7 | 2710 | 116 | 116 | 117 | 77 | 80 |
| France | 25 | 10 | 2520 | 134 | 137 | 141 | 64 | 79 |
| German Dem Rep | 31 | 12 | 2620 | 124 | 134 | 142 | X | X |
| Germany, Fed Rep | 28 | 13 | 2670 | 115 | 120 | 126 | X | X |
| Greece | 50 | 19 | 2500 | 124 | 141 | 143 | X | X |
| Hungary | 44 | 21 | 2630 | 120 | 130 | 133 | 67 | 74 |
| Ireland | 28 | 13 | 2510 | 137 | 142 | 158 | X | X |
| Italy | 40 | 14 | 2520 | 126 | 140 | 141 | X | 78 |
| Luxembourg | 29 | 11 | X | X | X | X | X | X |
| Malta | 34 | 15 | 2480 | 111 | 123 | 118 | X | X |
| Netherlands | 16 | 8 | 2690 | 127 | 131 | 134 | X | X |
| Norway | 17 | 8 | 2680 | 115 | 116 | 124 | X | 71 |
| Poland | 51 | 21 | 2620 | 123 | 133 | 128 | 60 | 75 |
| Portugal | 76 | 25 | 2450 | 112 | 128 | 127 | X | 66 |
| Romania | 60 | 26 | 2650 | 113 | 125 | 126 | X | 58 |
| Spain | 42 | 12 | 2460 | 116 | 133 | 134 | X | 51 |
| Sweden | 15 | 7 | 2690 | 111 | 117 | 119 | X | 78 |
| Switzerland | 20 | 8 | 2690 | 126 | 122 | 129 | X | X |
| United Kingdom | 22 | 12 | 2520 | 134 | 129 | 129 | 69 | 77 |
| Yugoslavia | 80 | 29 | 2540 | 127 | 137 | 143 | 59 | 55 |
| **USSR** | **32** | **25** | **2560** | **126** | **132** | **132** | **X** | **X** |
| **OCEANIA** | **55** | **39** | | | | | | |
| Australia | 20 | 11 | 2660 | 118 | 118 | 117 | X | X |
| Fiji | 63 | 28 | 2660 | 93 | 101 | 115 | X | X |
| New Zealand | 21 | 12 | 2640 | 131 | 136 | 136 | X | X |
| Papua New Guinea | 154 | 98 | 2660 | 73 | 77 | 79 | X | 5 |
| Solomon Islands | X | X | 2660 | 82 | 76 | 77 | X | X |
| **ANTARCTICA** | | | | | | | | |

**Sources:** U.N. Food and Agriculture Organization; U.N. Department of International Economic and Social Affairs; World Health Organization; The World Bank.
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

# Table 2.5 EDUCATION, 1970–80

| | Combined Primary and Secondary School Enrollment as Percentage of School-Age Population | | | | | |
|---|---|---|---|---|---|---|
| | Total | | Male | | Female | |
| | 1970 | 1980 | 1970 | 1980 | 1970 | 1980 |
| **WORLD** | **41** | **71** | **45** | **78** | **37** | **64** |
| **AFRICA** | **29** | **36** | **36** | **42** | **22** | **30** |
| Algeria | 45 | 64 | 57 | 74 | 34 | 54 |
| Angola | X | X | X | X | X | X |
| Benin | 24 | 40 | 33 | 55 | 15 | 25 |
| Botswana | 47 | 73 | 44 | 66 | 49 | 79 |
| Burkina Faso | 7 | 11 | 9 | 14 | 5 | 8 |
| Burundi | 17 | 15 | 24 | 19 | 11 | 12 |
| Cameroon | 50 | 64 | 59 | 72 | 41 | 56 |
| Cape Verde | X | X | X | X | X | X |
| Central African Rep | 36 | 41 | 51 | 55 | 22 | 28 |
| Chad | 18 | 19 | 28 | 29 | 9 | 10 |
| Comoros | 19 | 64 | 26 | 77 | 12 | 52 |
| Congo | X | X | X | X | X | X |
| Djibouti | X | X | X | X | X | X |
| Egypt | 55 | 64 | 69 | 77 | 40 | 51 |
| Equatorial Guinea | 48 | X | 57 | X | 39 | X |
| Ethiopia | 11 | 28 | 15 | 37 | 7 | 20 |
| Gabon | X | X | X | X | X | X |
| Gambia | 16 | 32 | 23 | 42 | 10 | 22 |
| Ghana | 52 | 52 | 61 | 61 | 43 | 44 |
| Guinea | 24 | 25 | 34 | 35 | 14 | 16 |
| Guinea-Bissau | 29 | 58 | 40 | 82 | 18 | 36 |
| Ivory Coast | 37 | 49 | 47 | 61 | 25 | 36 |
| Kenya | 41 | 73 | 49 | 78 | 33 | 68 |
| Lesotho | 62 | 72 | 49 | 58 | 74 | 85 |
| Liberia | 31 | 45 | 43 | 58 | 20 | 33 |
| Libya | X | X | X | X | X | X |
| Madagascar | 50 | 54 | 55 | 58 | 46 | 50 |
| Malawi | 23 | 44 | 30 | 52 | 17 | 36 |
| Mali | 15 | 19 | 20 | 25 | 10 | 13 |
| Mauritania | 8 | 23 | 13 | 31 | 4 | 15 |
| Mauritius | 62 | 72 | 65 | 73 | 59 | 72 |
| Morocco | 32 | 48 | 42 | 59 | 22 | 36 |
| Mozambique | X | 47 | X | 55 | X | 39 |
| Niger | 7 | 14 | 10 | 18 | 5 | 10 |
| Nigeria | 21 | X | 27 | X | 16 | X |
| Rwanda | 41 | 45 | 47 | 48 | 36 | 43 |
| Senegal | 24 | 29 | 31 | 36 | 18 | 22 |
| Sierra Leone | 22 | 26 | 28 | 32 | 17 | 20 |
| Somalia | 7 | 23 | 11 | 31 | 3 | 17 |
| South Africa | X | X | X | X | X | X |
| Sudan | 24 | 36 | 30 | 42 | 18 | 29 |
| Swaziland | 63 | 81 | 65 | 82 | 61 | 81 |
| Tanzania, United Rep | 24 | 62 | 30 | 66 | 19 | 58 |
| Togo | 39 | 75 | 55 | 98 | 24 | 53 |
| Tunisia | 63 | 64 | 79 | 75 | 48 | 53 |
| Uganda | 25 | 33 | 31 | 38 | 19 | 28 |
| Zaire | 52 | 59 | 67 | 72 | 37 | 47 |
| Zambia | 61 | 67 | 69 | 73 | 53 | 61 |
| Zimbabwe | 47 | 56 | 52 | 60 | 42 | 52 |
| **NORTH AMERICA** | **87** | **92** | **88** | **92** | **87** | **91** |
| Barbados | 89 | 99 | 90 | 98 | 88 | 99 |
| Canada | 87 | 94 | 87 | 94 | 86 | 94 |
| Costa Rica | 76 | 80 | 76 | 79 | 77 | 81 |
| Cuba | 75 | 91 | 75 | 91 | 76 | 90 |
| Dominican Rep | X | X | X | X | X | X |
| El Salvador | 60 | 63 | 61 | 63 | 58 | 63 |
| Guatemala | 35 | 45 | 38 | 48 | 32 | 41 |
| Haiti | X | 43 | X | 47 | X | 40 |
| Honduras | 58 | 69 | 58 | 69 | 58 | 69 |
| Jamaica | 82 | 77 | 82 | 75 | 82 | 79 |
| Mexico | 67 | 88 | 70 | 89 | 63 | 86 |
| Nicaragua | 54 | 77 | 54 | 74 | 54 | 80 |
| Panama | 76 | 90 | 76 | 90 | 75 | 91 |
| Trinidad and Tobago | 83 | 79 | 82 | 77 | 84 | 80 |
| United States | 100 | 99 | 99 | 99 | 100 | 99 |
| **SOUTH AMERICA** | **37** | **81** | **37** | **80** | **36** | **81** |
| Argentina | 81 | 93 | 80 | 91 | 83 | 95 |
| Bolivia | 61 | 70 | 72 | 76 | 50 | 64 |
| Brazil | X | 77 | X | 76 | X | 77 |
| Chile | 88 | 96 | 86 | 95 | 89 | 96 |
| Colombia | 67 | 83 | 66 | 81 | 67 | 86 |
| Ecuador | 63 | 77 | 64 | 77 | 62 | 76 |
| Guyana | 79 | 78 | 80 | 77 | 79 | 78 |
| Paraguay | 67 | 66 | 70 | 69 | 64 | 64 |
| Peru | 72 | 89 | 78 | 93 | 66 | 84 |
| Suriname | 92 | 78 | 93 | 79 | 92 | 77 |
| Uruguay | 86 | 82 | 85 | 81 | 86 | 83 |
| Venezuela | 69 | 74 | 69 | 75 | 70 | 73 |

# Table 2.5

| | Combined Primary and Secondary School Enrollment as Percentage of School-Age Population | | | | | |
|---|---|---|---|---|---|---|
| | Total | | Male | | Female | |
| | 1970 | 1980 | 1970 | 1980 | 1970 | 1980 |
| **ASIA** | **28** | **71** | **33** | **80** | **22** | **61** |
| Afghanistan | 19 | 26 | 32 | 41 | 5 | 10 |
| Bahrain | 83 | 81 | 94 | 85 | 71 | 75 |
| Bangladesh | X | 37 | X | 48 | X | 26 |
| Bhutan | 4 | 7 | 7 | 10 | 0 | 4 |
| Burma | 54 | 51 | 59 | 54 | 49 | 49 |
| China | X | 88 | X | 98 | X | 77 |
| Cyprus | X | X | X | X | X | X |
| India | 49 | 53 | 63 | 65 | 35 | 41 |
| Indonesia | 49 | 71 | 55 | 78 | 43 | 65 |
| Iran | 52 | 68 | 67 | 81 | 37 | 55 |
| Iraq | 49 | 90 | 68 | 101 | 29 | 78 |
| Israel | 83 | 88 | 83 | 86 | 83 | 91 |
| Japan | 92 | 98 | 93 | 97 | 92 | 98 |
| Jordan | X | 92 | X | 93 | X | 90 |
| Kampuchea, Dem | X | X | X | X | X | X |
| Korea, Dem People's Rep | X | X | X | X | X | X |
| Korea, Rep | 76 | 94 | 80 | 97 | 71 | 91 |
| Kuwait | 76 | 84 | 84 | 87 | 66 | 79 |
| Lao People's Dem Rep | 29 | 57 | 36 | 63 | 21 | 51 |
| Lebanon | 77 | 83 | 85 | 86 | 68 | 80 |
| Malaysia | 62 | 71 | 66 | 72 | 57 | 69 |
| Mongolia | X | 94 | X | 93 | X | 95 |
| Nepal | 18 | 44 | 30 | 64 | 6 | 23 |
| Oman | X | 41 | X | 54 | X | 27 |
| Pakistan | 25 | 35 | 37 | 50 | 13 | 18 |
| Philippines | X | 92 | X | 91 | X | 93 |
| Qatar | 77 | 87 | 80 | 84 | 71 | 93 |
| Saudi Arabia | 30 | 50 | 42 | 59 | 18 | 39 |
| Singapore | 77 | 79 | 79 | 79 | 74 | 80 |
| Sri Lanka | 71 | 74 | 72 | 74 | 69 | 73 |
| Syrian Arab Rep | 61 | 76 | 78 | 87 | 43 | 64 |
| Thailand | 58 | 65 | 61 | 67 | 55 | 62 |
| Turkey | 67 | 71 | 80 | 82 | 53 | 60 |
| United Arab Emirates | 65 | 86 | 75 | 84 | 48 | 91 |
| Viet Nam | X | 77 | X | 84 | X | 71 |
| Yemen | 7 | 27 | 14 | 49 | 1 | 7 |
| Yemen, Dem | 37 | 51 | 59 | 73 | 15 | 29 |
| **EUROPE** | **81** | **85** | **82** | **84** | **80** | **86** |
| Albania | 86 | 93 | 90 | 97 | 81 | 89 |
| Austria | 84 | 81 | 84 | 80 | 84 | 82 |
| Belgium | 92 | 95 | 93 | 94 | 92 | 95 |
| Bulgaria | 95 | 93 | 95 | 94 | 94 | 93 |
| Czechoslovakia | 76 | 78 | 73 | 74 | 78 | 82 |
| Denmark | 87 | 101 | 89 | 102 | 86 | 101 |
| Finland | 92 | 97 | 91 | 94 | 93 | 99 |
| France | 92 | 96 | 90 | 92 | 93 | 100 |
| German Dem Rep | X | X | X | X | X | X |
| Germany, Fed Rep | 78 | 79 | 78 | 78 | 78 | 80 |
| Greece | 85 | 91 | 90 | 94 | 81 | 89 |
| Hungary | 72 | 80 | 70 | 78 | 74 | 82 |
| Ireland | 92 | 97 | 91 | 95 | 93 | 100 |
| Italy | 81 | 84 | 85 | 85 | 77 | 83 |
| Luxembourg | 81 | 79 | 82 | 78 | 81 | 79 |
| Malta | 78 | 89 | 80 | 92 | 76 | 87 |
| Netherlands | 88 | 97 | 91 | 98 | 86 | 96 |
| Norway | 87 | 99 | 85 | 98 | 89 | 99 |
| Poland | 87 | 92 | 88 | 92 | 87 | 92 |
| Portugal | 80 | 88 | 84 | 89 | 77 | 88 |
| Romania | 87 | 93 | 89 | 94 | 85 | 92 |
| Spain | 88 | 97 | 91 | 96 | 85 | 97 |
| Sweden | 90 | 92 | 90 | 90 | 90 | 94 |
| Switzerland | X | X | X | X | X | X |
| United Kingdom | 88 | 91 | 89 | 90 | 88 | 92 |
| Yugoslavia | 77 | 88 | 81 | 91 | 73 | 86 |
| **USSR** | **X** | **X** | **X** | **X** | **X** | **X** |
| **OCEANIA** | **89** | **88** | **91** | **89** | **87** | **88** |
| Australia | 101 | 99 | 101 | 99 | 100 | 100 |
| Fiji | 82 | 92 | 84 | 92 | 79 | 93 |
| New Zealand | 93 | 91 | 94 | 91 | 92 | 92 |
| Papua New Guinea | 32 | 40 | 40 | 46 | 24 | 33 |
| Solomon Islands | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | |

**Source:** United Nations Educational, Scientific and Cultural Organization.
0=zero or less than one-half the unit of measure; X=not available.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 2.1 Estimated Size and Growth of Population, 1960–2005

**Source:** U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Population refers to the midyear population. Most data are estimates based on population censuses and surveys. All projections are for the medium-case scenario. (See discussion below.) The average annual growth rate of population takes into account the effects of international migration.

Many of the pre-1980 data in Tables 2.1–2.4 are estimated using models. Several kinds of demographic information are required to estimate the growth and composition of a country's population: the size of the population; age and sex distribution; fertility and mortality rates by age and sex groups; the growth rates of both the urban and rural populations; and levels of internal and international migration.

Recent population censuses and surveys have collected information needed to calculate or estimate the above indicators, although the degree of accuracy varies. The Population Division of the U.N. Department of International Economic and Social Affairs compiles and evaluates national census and survey reports from all countries. When necessary, the data are adjusted for underenumeration of certain age and sex groups (infants, female children, young males), misreporting of age and sex distributions, changes in definitions, etc. These adjustments incorporate information from civil registrations, population surveys, earlier censuses, other sources, and population models. (Because the figures have been adjusted, they are not strictly comparable to the official statistics compiled by the U.N. Statistical Office and published in the *Demographic Yearbook.)*

After the figures for size and age/sex composition of the population have been adjusted, the data are scaled to 1980. Because most countries conducted a population census or large-scale population survey in the 1970s or early 1980s, the scaling is usually minor. Similar estimates are made for each five-year period between 1980 and 1950. Historical data are used when deemed accurate, with adjustments and scaling similar to those described above. For many developing countries, however, accurate historical data do not exist. The Population Division estimates the main demographic parameters for these countries using available information and demographic models.

Projections are based on estimates of the 1980 base year population. Age- and sex-specific mortality rates are applied to the base year population to determine the number of survivors at the end of each five-year period. Future births are projected by applying age-specific fertility rates to the projected female population. The births are distributed by an assumed sex ratio, and the appropriate age- and sex-specific survival rates are applied. Future migration rates are also estimated on an age- and sex-specific basis. Combining future fertility, mortality, and migration rates yields the projected size and composition of the population.

Assumptions about future mortality, fertility, and migration—the three components of population growth—are made on a country-by-country basis and, whenever possible, are based on historical trends. Four scenarios of population growth (high, medium, low, and constant) are created using different assumptions about these rates. The medium-case scenario, for example, assumes medium levels of fertility, mortality, and migration, assumptions that may vary widely among the countries. The medium mortality assumption includes a quinquennial gain of 2.5 years in life expectancy at birth until it reaches 62.5 years. Life expectancy is assumed to increase more slowly thereafter. However, for the countries that have had little or no reduction in mortality recently (some sub-Saharan African and South Asian countries), the quinquennial gain in life expectancy was assumed to be 2 years or less. Refer to the source for further details.

### Table 2.2 Births, Deaths, Fertility, and Mortality, 1950–85

**Source:** U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

The crude birth rate is the number of live births in a given year divided by the midyear population and multiplied by 1,000.

The crude death rate is the number of deaths in a given year divided by the midyear population and multiplied by 1,000.

The total fertility rate is an estimate of the number of children an average woman would have if current age-specific fertility rates remained constant during her reproductive years.

Life expectancy at birth is the average number of years a newborn baby is expected to live if the age-specific death rates effective at the year of its birth are applied.

For details on data collection, estimation, and projection methods, refer to the sources or to the Technical Note for Table 2.1.

### Table 2.3 Age Distribution, 1960–2000

**Source:** U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Age distribution estimates refer to the total population. The male and female age distributions differ from the age distribution of the total population and from each other. For details on methods of data collection, estimation, and projection, refer to the sources or to the Technical Note for Table 2.1.

### Table 2.4 Health Indicators, 1960–85

**Sources:** Infant mortality: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985). Minimum daily requirement of calories and calorie supply as percentage of requirements for 1980–82: U.N. Food and Agriculture Organization (FAO), *State of Food and Agriculture 1984* (FAO, Rome, 1985). Calorie supply as percentage of requirements for 1964–66 and 1974–76: FAO, *Production Yearbook 1983* (FAO, Rome, 1984). Percentage of married couples of childbearing age using contraception: The World Bank, *World Development Report 1985* (The World Bank, Washington, D.C., 1985).

The infant mortality rate is the number of babies who die before their first birthdays in a given year divided by the number of live births in that year and multiplied by 1,000.

The minimum daily calorie requirement is the energy intake necessary to meet the energy needs of an average healthy person. It is calculated for each country by the World Health Organization, which takes into account body size, age and sex distribution, physical activity level of the population, climate, and other factors.

The calorie supply as a percentage of requirements includes calories from all sources: domestic production, international trade, stock drawdowns, and foreign aid. The quantity of food available for human consumption, as estimated by FAO, is the food that reaches the consumer. The amount of food actually consumed may be lower than the figures show, depending on how much is lost in home storage, preparation, and cooking plus what is fed to pets and domestic animals or is thrown away.

The percentage of married couples using contraception includes women of childbearing age (or their husbands) who use any method of contraception. Data for 1970 refer approximately to 1968–72; data for 1982 refer generally to 1980–84.

### Table 2.5 Education, 1970–80

**Source:** U.N. Statistical Office, *Selected Statistics and Indicators on the Status of Women* (United Nations, New York, 1985).

The number of students enrolled in primary and secondary schools is derived from the annual *Statistical Yearbook* of the U.N. Educational, Scientific and Cultural Organization. The age-specific population estimates are prepared by the Population Division of the U.N. Secretariat.

The combined primary and secondary enrollment rate is the ratio of total primary and secondary enrollment (regardless of age) to the number of persons in the primary and secondary age groups. The ratio may overstate the actual percentage of the population of primary- and secondary-age children enrolled because the denominator may not cover the entire range of ages covered by the numerator.

For example, the percentage of school-age children enrolled in school in Demark is reported in the tables as 101 percent. This indicates that some students are younger or older than the standard age groups used to form the demoninator.

Differences in the enrollment ratio may reflect the different definitions used, variations in the quality of the statistics, and different attendance patterns.

# 3. Human Settlements

This section provides data on two important aspects of human settlements: patterns of population distribution and living conditions.

Tables 3.1 and 3.3 include the latest estimates of the number of people living in urban and rural areas, the percentage living in cities over 100,000, and the 25 largest cities of the world.

As important as cities and towns have been throughout history, no single internationally recognized definition of urban population exists. As a result, countries supply the United Nations with data based on definitions shaped by local and national customs. Despite differences, however, these data indicate remarkable urban growth. The period between 1960 and 1985 saw an increase in the fraction of the population living in urban areas and rapid growth of cities of more than 100,000 people. But all population growth did not occur in cities and towns. Between 1980–85 rural populations grew in 46 of 49 African countries; 13 of 15 North and Central American countries; 7 of 12 in South America; 30 of 37 in Asia; and 3 of 26 in Europe.

The largest cities of the world increasingly appear in rapidly developing countries that support large, diverse labor forces. Most of these huge cities are still growing in population and area. They are doing so, though, at lower rates than 10 or 20 years ago. For instance, Mexico City grew by 92 percent between 1955 and 1965, by 75 percent between 1965 and 1975, and by 52 percent between 1975 and 1985.

Access to safe drinking water and sanitation is fundamental to development. Data for rural and urban populations, shown in Table 3.2, were compiled by the World Health Organization (WHO) for the International Drinking Water Supply and Sanitation Decade (1980–90). The data represent the situation in developing countries in the early 1980s. The information is the latest available from WHO's ongoing program to develop baseline information, establish targets, and assess progress in this field. Industrial countries are not included, but they routinely report that between 90 and 100 percent of their populations have access to safe drinking water and sanitation facilities.

Statistics on access to safe drinking water, particularly for rural areas, have been difficult to collect in a valid and reliable manner. Technical problems include defining what is meant by "access;" testing to determine safe levels of contaminants; determining if treatment facilities are operating; etc. Other problems stem from institutional and political conflicts. Some countries report high levels of access to demonstrate substantial progress in development. Others may report low levels to establish a record for seeking international aid for rural development and public water supply projects. Despite problems with the data, they show clearly that hundreds of millions of people do not have adequate access to safe drinking water and sanitation. Countries reporting especially poor access include Mali, Uganda, Bolivia, Paraguay, Nepal, Lao PDR, Bhutan, and Papua New Guinea.

One of the most costly environmental problems facing industrialized countries is the control of wastes, particularly hazardous wastes. Table 3.4 shows information on municipal, industrial, and hazardous wastes. The data shown for hazardous wastes are the amounts generated principally by industry. They are based on definitions, regulations, and collection methods unique to each country. In the United States, 32 of 50 states define hazardous waste (based on existing laws and regulations) differently from the U.S. Environmental Protection Agency. Since 1976, four major studies have estimated the total annual amount of hazardous waste produced in the United States. The results ranged from 41 million to 264 million metric tons per year. The high figure, based on studies completed in 1984, is believed to be the best approximation of the amount of hazardous waste that requires treatment or long-term safe disposal as mandated by the Resources Conservation and Recovery Act.

# Table 3.1 POPULATION DISTRIBUTION, 1960–85

| | Urban Population as Percentage of Total | | Average Annual Population Growth Rate (percent) | | | | Percentage of Total Population Living in Cities of over 100,000 | |
|---|---|---|---|---|---|---|---|---|
| | | | Urban | | Rural | | | |
| | 1960 | 1985 | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1960 | 1980 |
| **WORLD** | **33.6** | **41.6** | **3.1** | **2.5** | **1.3** | **1.1** | | |
| **AFRICA** | **18.4** | **32.1** | **4.6** | **5.2** | **1.9** | **2.0** | | |
| Algeria | 30.4 | 66.6 | 6.2 | 5.1 | −0.2 | 0.1 | 17.1 | 15.6 |
| Angola | 10.4 | 24.5 | 5.1 | 5.6 | 1.0 | 1.6 | 4.6 | 13.3 |
| Benin | 9.5 | 38.5 | 5.2 | 7.3 | 1.2 | 0.5 | 6.5 | 22.6 |
| Botswana | 1.8 | 19.2 | 18.6 | 8.0 | 2.2 | 2.5 | 0.3 | 5.9 |
| Burkina Faso | 4.7 | 7.9 | 3.7 | 4.7 | 1.5 | 2.1 | 2.5 | 6.2 |
| Burundi | 2.2 | 2.5 | 1.9 | 4.4 | 1.9 | 2.6 | 2.2 | 2.2 |
| Cameroon | 13.9 | 42.4 | 5.3 | 6.6 | 1.4 | 0.0 | 5.0 | 11.9 |
| Cape Verde | 7.0 | 6.1 | 1.6 | 2.2 | 2.9 | 1.3 | X | X |
| Central African Rep | 22.7 | 45.7 | 4.7 | 4.5 | 0.4 | 0.6 | 9.0 | 14.7 |
| Chad | 7.0 | 21.6 | 6.6 | 6.1 | 1.3 | 1.3 | 2.5 | 7.0 |
| Comoros | 5.1 | 14.0 | 6.5 | 6.8 | 2.0 | 2.5 | X | X |
| Congo | 33.0 | 39.5 | 2.6 | 3.7 | 1.8 | 1.9 | 33.1 | 37.1 |
| Djibouti | X | X | X | X | X | 0.0 | 49.2 | 70.7 |
| Egypt | 37.9 | 46.5 | 3.9 | 3.3 | 1.6 | 1.9 | 28.3 | 33.5 |
| Equatorial Guinea | 25.5 | 59.7 | 5.8 | 4.3 | −0.5 | −0.6 | 25.4 | 55.6 |
| Ethiopia | 6.4 | 17.6 | 5.7 | 6.5 | 2.1 | 1.9 | 2.5 | 6.8 |
| Gabon | 17.4 | 40.9 | 4.8 | 4.3 | −0.1 | 0.0 | 6.6 | 24.1 |
| Gambia | 12.4 | 20.9 | 4.1 | 4.3 | 2.0 | 1.4 | 12.4 | 18.5 |
| Ghana | 23.3 | 39.6 | 5.1 | 5.2 | 2.0 | 2.0 | 11.0 | 19.0 |
| Guinea | 9.9 | 22.2 | 5.1 | 5.4 | 1.3 | 1.5 | 3.7 | 15.2 |
| Guinea-Bissau | 13.6 | 27.1 | 2.3 | 4.5 | −1.1 | 1.0 | 4.9 | 8.6 |
| Ivory Coast | 19.3 | 42.0 | 7.4 | 5.9 | 2.8 | 1.8 | 6.6 | 15.4 |
| Kenya | 7.4 | 16.7 | 6.6 | 7.4 | 3.2 | 3.5 | 4.9 | 10.6 |
| Lesotho | 1.5 | 5.8 | 7.6 | 7.4 | 1.9 | 2.3 | 1.5 | 4.5 |
| Liberia | 18.6 | 39.5 | 6.0 | 5.6 | 1.7 | 1.7 | 9.3 | 15.9 |
| Libya | 22.7 | 64.5 | 6.5 | 6.4 | 2.8 | −0.1 | 20.6 | 31.6 |
| Madagascar | 10.6 | 21.8 | 5.2 | 5.7 | 1.8 | 2.1 | 4.6 | 6.7 |
| Malawi | 4.4 | 12.0 | 4.6 | 7.6 | 2.3 | 2.7 | 1.6 | 4.3 |
| Mali | 11.1 | 20.8 | 4.5 | 5.3 | 1.6 | 2.2 | 3.5 | 7.5 |
| Mauritania | 6.7 | 34.6 | 9.9 | 8.0 | 1.7 | 0.7 | 0.5 | 16.8 |
| Mauritius | 33.2 | 56.8 | 5.4 | 3.6 | 2.0 | −0.1 | 16.8 | 14.8 |
| Morocco | 29.3 | 43.9 | 4.4 | 4.9 | 2.0 | 2.1 | 26.7 | 31.4 |
| Mozambique | 3.7 | 19.4 | 6.5 | 10.9 | 1.9 | 1.5 | 2.8 | 6.0 |
| Niger | 5.8 | 16.2 | 6.1 | 6.9 | 2.7 | 2.1 | 1.1 | 4.1 |
| Nigeria | 13.1 | 23.0 | 5.0 | 5.8 | 2.4 | 2.7 | 9.7 | 17.6 |
| Rwanda | 2.4 | 5.1 | 5.8 | 6.8 | 2.9 | 3.3 | X | X |
| Senegal | 22.4 | 42.4 | 5.5 | 4.9 | 1.7 | 1.2 | 16.4 | 21.7 |
| Sierra Leone | 13.0 | 28.3 | 4.7 | 4.6 | 0.8 | 0.8 | 7.2 | 15.7 |
| Somalia | 17.3 | 34.1 | 4.9 | 6.2 | 1.3 | 2.6 | 6.3 | 11.2 |
| South Africa | 46.7 | 55.9 | 2.4 | 3.5 | 1.9 | 1.3 | 26.9 | 25.7 |
| Sudan | 10.3 | 29.4 | 6.8 | 6.3 | 1.4 | 1.6 | 4.3 | 9.7 |
| Swaziland | 3.9 | 26.3 | 12.4 | 8.7 | 1.8 | 1.3 | 2.1 | 5.1 |
| Tanzania, United Rep | 4.8 | 14.8 | 5.7 | 8.1 | 2.7 | 2.8 | 1.6 | 5.9 |
| Togo | 9.8 | 20.1 | 4.4 | 5.7 | 1.1 | 2.2 | 5.4 | 10.5 |
| Tunisia | 36.0 | 56.8 | 3.7 | 4.0 | 0.7 | 0.4 | 17.8 | 20.7 |
| Uganda | 5.2 | 14.4 | 8.3 | 7.3 | 3.8 | 2.9 | 2.0 | 6.1 |
| Zaire | 22.3 | 44.2 | 5.0 | 5.2 | 0.9 | 1.3 | 10.0 | 23.1 |
| Zambia | 17.2 | 49.5 | 8.9 | 6.2 | 1.3 | 0.8 | 15.2 | 32.3 |
| Zimbabwe | 12.6 | 24.6 | 6.8 | 5.8 | 3.7 | 2.8 | 9.4 | 17.3 |
| **NORTH AMERICA** | **63.2** | **70.0** | **2.5** | **1.8** | **0.7** | **0.7** | | |
| Barbados | 35.4 | 42.2 | 0.8 | 1.8 | 0.1 | 0.1 | 35.4 | 38.6 |
| Canada | 68.9 | 75.0 | 3.0 | 1.2 | −0.9 | 1.2 | 44.2 | 55.0 |
| Costa Rica | 36.6 | 45.9 | 4.5 | 3.8 | 3.1 | 1.7 | 24.4 | 27.3 |
| Cuba | 54.9 | 71.8 | 3.1 | 1.7 | 0.9 | −1.8 | 31.2 | 33.3 |
| Dominican Rep | 30.2 | 55.7 | 5.9 | 4.3 | 1.5 | 0.1 | 19.1 | 37.1 |
| El Salvador | 38.3 | 43.0 | 3.4 | 3.8 | 2.9 | 2.3 | 13.0 | 11.5 |
| Guatemala | 33.0 | 41.4 | 3.8 | 4.1 | 2.6 | 2.1 | 13.6 | 14.2 |
| Haiti | 15.6 | 28.0 | 4.5 | 4.9 | 1.6 | 1.7 | 6.6 | 13.9 |
| Honduras | 22.7 | 39.9 | 5.9 | 5.4 | 2.6 | 2.1 | 9.9 | 19.0 |
| Jamaica | 33.8 | 53.8 | 3.7 | 2.9 | 0.4 | −0.3 | 26.1 | 33.1 |
| Mexico | 50.8 | 70.0 | 4.8 | 3.6 | 1.4 | 0.5 | 28.8 | 43.2 |
| Nicaragua | 39.6 | 59.4 | 4.7 | 4.7 | 2.1 | 1.5 | 14.1 | 28.5 |
| Panama | 41.2 | 51.9 | 4.4 | 2.9 | 1.8 | 1.5 | 28.2 | 37.7 |
| Trinidad and Tobago | 22.2 | 22.6 | 2.6 | 1.9 | 3.0 | 0.6 | 11.3 | 6.8 |
| United States | 70.0 | 74.2 | 2.0 | 1.0 | 0.2 | 0.5 | 52.4 | 56.5 |
| **SOUTH AMERICA** | **51.7** | **72.4** | **4.3** | **3.3** | **0.8** | **−0.3** | | |
| Argentina | 73.6 | 84.6 | 2.2 | 2.0 | −0.4 | −0.7 | 53.0 | 58.3 |
| Bolivia | 39.3 | 43.7 | 2.7 | 3.3 | 2.0 | 2.2 | 19.4 | 28.6 |
| Brazil | 44.9 | 72.7 | 5.3 | 3.7 | 0.9 | −1.3 | 28.3 | 43.0 |
| Chile | 67.8 | 83.4 | 3.4 | 2.2 | −0.3 | −0.8 | 36.0 | 47.5 |
| Colombia | 48.2 | 67.4 | 5.2 | 3.1 | 0.9 | 0.3 | 32.1 | 43.4 |
| Ecuador | 34.4 | 47.7 | 4.5 | 4.4 | 2.1 | 2.0 | 19.6 | 24.6 |
| Guyana | 29.0 | 32.2 | 2.7 | 3.0 | 2.5 | 1.5 | 26.4 | 20.9 |
| Paraguay | 35.6 | 41.5 | 2.9 | 4.0 | 2.3 | 2.3 | 15.8 | 17.3 |
| Peru | 46.3 | 67.4 | 5.2 | 3.5 | 0.7 | 0.9 | 26.5 | 41.3 |
| Suriname | 47.3 | 45.7 | 2.7 | 0.4 | 2.8 | −0.3 | 35.9 | 20.8 |
| Uruguay | 80.1 | 85.0 | 1.4 | 0.9 | 0.2 | −0.6 | 45.4 | 40.5 |
| Venezuela | 66.6 | 85.7 | 5.4 | 3.8 | 0.6 | 0.2 | 35.2 | 48.0 |

# Table 3.1

| | Urban Population as Percentage of Total | | Average Annual Population Growth Rate (percent) | | | | Percentage of Total Population Living in Cities of over 100,000 | |
|---|---|---|---|---|---|---|---|---|
| | | | Urban | | Rural | | | |
| | 1960 | 1985 | 1960–65 | 1980–85 | 1960–65 | 1980–85 | 1960 | 1980 |
| **ASIA** | **20.6** | **28.2** | **3.9** | **2.9** | **1.6** | **1.3** | | |
| Afghanistan | 8.0 | 18.5 | 5.2 | 3.4 | 1.8 | –0.7 | 4.4 | 11.3 |
| Bahrain | 78.6 | 81.7 | 4.0 | 4.6 | 4.1 | 3.1 | 43.2 | 37.7 |
| Bangladesh | 5.1 | 11.9 | 6.3 | 5.4 | 2.2 | 2.4 | 3.8 | 7.8 |
| Bhutan | 2.5 | 4.5 | 4.0 | 4.9 | 1.8 | 1.9 | X | X |
| Burma | 19.3 | 30.0 | 4.0 | 4.5 | 1.9 | 1.7 | 8.2 | 11.1 |
| China | 16.8 | 21.0 | 4.4 | 1.9 | 1.2 | 1.0 | 11.5 | 11.1 |
| Cyprus | 35.6 | 49.5 | 1.7 | 2.5 | –0.5 | –0.1 | 16.5 | 18.9 |
| India | 18.0 | 25.5 | 3.4 | 3.7 | 2.3 | 1.4 | 10.7 | 14.4 |
| Indonesia | 14.6 | 25.3 | 3.7 | 4.4 | 1.9 | 0.9 | 11.0 | 14.3 |
| Iran | 33.6 | 55.0 | 5.2 | 4.7 | 2.4 | 1.1 | 21.5 | 31.2 |
| Iraq | 42.9 | 70.6 | 6.4 | 4.7 | 0.1 | 0.7 | 28.4 | 69.3 |
| Israel | 77.0 | 90.7 | 4.9 | 2.4 | 0.1 | –1.1 | 54.9 | 49.3 |
| Japan | 62.5 | 76.5 | 2.5 | 0.6 | –1.7 | 0.3 | 33.7 | 45.6 |
| Jordan | 42.7 | 64.4 | 4.5 | 5.0 | 1.6 | 1.4 | 20.7 | 33.8 |
| Kampuchea, Dem | 10.3 | 15.6 | 3.5 | 5.2 | 2.3 | 2.5 | 7.2 | 8.9 |
| Korea, Dem People's Rep | 40.2 | 63.8 | 5.1 | 3.6 | 1.1 | 0.2 | 16.9 | 24.9 |
| Korea, Rep | 27.7 | 65.3 | 5.7 | 4.2 | 1.3 | –3.0 | 28.2 | 55.6 |
| Kuwait | 72.3 | 93.7 | 12.0 | 6.0 | 6.2 | –3.5 | 77.9 | 74.0 |
| Lao People's Dem Rep | 7.9 | 15.9 | 3.3 | 5.8 | 2.3 | 1.9 | 5.5 | 6.5 |
| Lebanon | 39.6 | 80.4 | 7.4 | 1.2 | –0.6 | –4.5 | 32.4 | 68.6 |
| Malaysia | 25.2 | 31.5 | 3.7 | 3.7 | 2.8 | 1.7 | 11.3 | 12.5 |
| Mongolia | 35.7 | 55.9 | 6.1 | 4.0 | 0.7 | 1.1 | 18.9 | 26.7 |
| Nepal | 3.1 | 5.8 | 4.3 | 5.3 | 1.8 | 2.2 | 1.3 | 1.4 |
| Oman | 3.5 | 8.8 | 6.2 | 8.2 | 2.3 | 4.2 | 2.7 | 4.2 |
| Pakistan | 22.1 | 29.8 | 3.9 | 4.3 | 2.3 | 2.6 | 12.1 | 17.9 |
| Philippines | 30.3 | 39.6 | 3.9 | 3.7 | 2.7 | 1.7 | 16.2 | 21.6 |
| Qatar | 72.4 | 88.0 | 10.0 | 4.5 | 5.6 | 1.0 | 72.4 | 86.1 |
| Saudi Arabia | 29.7 | 73.0 | 8.6 | 5.7 | 0.5 | –0.2 | 13.2 | 40.4 |
| *Singapore* | 77.6 | 74.2 | 2.5 | 1.3 | *3.8* | 1.2 | *77.6* | 74.1 |
| Sri Lanka | 17.9 | 21.1 | 4.5 | 1.6 | 1.9 | 2.2 | 8.9 | 8.2 |
| Syrian Arab Rep | 36.8 | 47.4 | 4.8 | 4.5 | 2.0 | 2.9 | 29.0 | 32.2 |
| Thailand | 12.5 | 15.6 | 3.6 | 3.8 | 2.9 | 1.8 | 8.2 | 9.9 |
| Turkey | 29.7 | 48.1 | 5.2 | 3.8 | 1.2 | 1.1 | 18.9 | 33.4 |
| United Arab Emirates | 40.0 | 77.8 | 16.3 | 5.0 | 3.0 | 9.2 | 11.5 | 23.4 |
| Viet Nam | 14.7 | 20.3 | 4.4 | 3.1 | 1.8 | 1.8 | 13.2 | 10.6 |
| Yemen | 3.4 | 20.0 | 10.1 | 7.8 | 1.8 | 1.2 | 1.8 | 3.2 |
| Yemen, Dem | 28.0 | 39.9 | 3.6 | 4.2 | 1.7 | 1.7 | 10.9 | 21.8 |
| **EUROPE** | **60.5** | **73.3** | **1.8** | **0.9** | **–0.6** | **–1.3** | | |
| Albania | 30.6 | 39.3 | 4.0 | 3.5 | 2.5 | 1.4 | 8.3 | 9.3 |
| Austria | 49.9 | 56.1 | 0.9 | 0.5 | 0.2 | –0.7 | 36.0 | 34.3 |
| Belgium | 84.6 | 89.2 | 1.1 | 0.1 | –1.7 | –0.6 | 29.8 | 26.4 |
| Bulgaria | 38.6 | 68.6 | 4.3 | 1.8 | –1.7 | –2.2 | 16.5 | 25.3 |
| Czechoslovakia | 46.9 | 66.3 | 2.4 | 1.5 | –0.9 | –1.5 | 15.5 | 16.4 |
| Denmark | 73.7 | 85.9 | 1.7 | 0.5 | –2.0 | –2.2 | 38.2 | 35.8 |
| *Finland* | *38.1* | 66.9 | 3.5 | *1.8* | *–1.4* | –2.3 | *16.1* | 24.7 |
| France | 62.4 | 77.2 | 2.8 | 0.8 | –1.4 | –1.4 | 40.0 | 46.3 |
| German Dem Rep | 72.3 | 78.2 | –0.1 | 0.3 | –0.8 | –1.5 | 23.2 | 24.8 |
| Germany, Fed Rep | 77.4 | 86.1 | 1.8 | 0.1 | –0.7 | –2.1 | 52.9 | 54.1 |
| Greece | 42.9 | 65.9 | 2.6 | 1.8 | –1.2 | –1.6 | 31.5 | 40.7 |
| Hungary | 40.0 | 57.0 | 1.6 | 1.4 | –0.6 | –1.4 | 23.8 | 29.7 |
| Ireland | 45.8 | 57.0 | 1.5 | 1.7 | –0.8 | 0.3 | 27.4 | 19.9 |
| Italy | 59.4 | 71.7 | 1.5 | 0.9 | –0.6 | –1.4 | 40.6 | 49.7 |
| Luxembourg | 62.1 | 81.8 | 1.4 | 0.7 | 0.6 | –3.6 | 22.7 | 22.5 |
| Malta | 70.0 | 85.4 | 0.5 | 1.2 | –3.4 | –2.0 | 5.3 | 4.3 |
| Netherlands | 76.8 | 92.5 | 1.6 | 1.3 | 0.7 | –8.3 | 37.6 | 39.3 |
| Norway | 32.1 | 80.3 | 3.5 | 3.2 | –0.6 | –8.5 | 22.8 | 24.3 |
| Poland | 47.9 | 59.2 | 2.1 | 1.8 | 0.4 | –0.3 | 29.0 | 32.8 |
| Portugal | 22.5 | 31.2 | 2.4 | 1.8 | 0.4 | 0.2 | 15.0 | 17.5 |
| Romania | 34.2 | 54.8 | 2.6 | 2.4 | –0.4 | –1.0 | 20.8 | 26.9 |
| Spain | 56.6 | 77.4 | 2.6 | 1.6 | –1.3 | –1.8 | 35.5 | 50.8 |
| Sweden | 72.6 | 85.5 | 1.9 | 0.3 | –2.9 | –1.7 | 25.9 | 46.3 |
| Switzerland | 51.0 | 60.4 | 2.5 | 0.5 | 1.0 | –1.4 | 30.8 | 38.9 |
| United Kingdom | 85.7 | 91.7 | 1.1 | 0.2 | –1.3 | –2.1 | 70.3 | 67.8 |
| Yugoslavia | 27.9 | 46.3 | 3.3 | 2.5 | 0.1 | –0.7 | 9.8 | 17.0 |
| **USSR** | **48.8** | **66.3** | **2.9** | **1.9** | **0.0** | **–0.8** | **27.9** | **36.2** |
| **OCEANIA** | **66.3** | **71.7** | **2.8** | **1.5** | **0.7** | **1.4** | | |
| Australia | 80.6 | 86.8 | 2.6 | 1.4 | –0.6 | 0.5 | 60.0 | 73.1 |
| Fiji | 29.7 | 41.2 | 5.1 | 2.9 | 2.4 | 0.8 | 16.4 | 21.3 |
| New Zealand | 76.0 | 83.7 | 2.8 | 0.8 | –0.5 | 0.3 | 42.5 | 50.0 |
| *Papua New Guinea* | *2.7* | 14.3 | *15.4* | 4.5 | 1.7 | 2.4 | *1.1* | 4.1 |
| Solomon Islands | X | X | X | X | X | X | 6.0 | 8.1 |
| **ANTARCTICA** | | | | | | | | |

**Sources:** U.N. Department of International Economic and Social Affairs; The World Bank.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 3.2 DRINKING WATER AND SANITATION, EARLY 1980s

| | Percentage of Population with Access to Safe Drinking Water | | | Percentage of Population with Access to Sanitation Services | | |
|---|---|---|---|---|---|---|
| | Total | Urban | Rural | Total | Urban | Rural |
| **WORLD** | | | | | | |
| **AFRICA** | | | | | | |
| Algeria | X | X | X | X | X | X |
| Angola | 28 | 90 | 12 | 18 | 29 | 15 |
| Benin | 18 | 26 | 15 | 18 | 48 | 4 |
| Botswana | 55 | 98 | 47 | 33 | 90 | 23 |
| Burkina Faso | 31 | 27 | 31 | 7 | 38 | 5 |
| Burundi | 24 | 90 | 22 | 52 | 50 | 52 |
| Cameroon | X | X | X | X | X | X |
| Cape Verde | 31 | 99 | 27 | 10 | 49 | 8 |
| Central African Rep | X | X | X | X | X | X |
| Chad | X | X | X | X | X | X |
| Comoros | X | X | X | X | X | X |
| Congo | 20 | 42 | 7 | X | X | X |
| Djibouti | 40 | 80 | 40 | 18 | 75 | 18 |
| Egypt | 75 | 88 | 64 | 26 | 45 | 10 |
| Equatorial Guinea | 25 | 47 | X | X | 99 | X |
| Ethiopia | X | X | X | X | X | X |
| Gabon | X | X | X | X | X | X |
| Gambia | 48 | 100 | 36 | X | X | X |
| Ghana | 51 | 72 | 39 | 27 | 47 | 16 |
| Guinea | 15 | 69 | 2 | 11 | 54 | 1 |
| Guinea-Bissau | 33 | 21 | 37 | 15 | 6 | 18 |
| Ivory Coast | X | X | X | X | X | X |
| Kenya | 27 | 61 | 21 | 44 | 75 | 39 |
| Lesotho | 12 | 37 | 11 | 14 | 13 | 14 |
| Liberia | 38 | 71 | 20 | 21 | 24 | 20 |
| Libya | 96 | 100 | 90 | 88 | 100 | 72 |
| Madagascar | 21 | 73 | 9 | X | 3 | X |
| Malawi | 41 | 77 | 37 | 83 | 100 | 81 |
| Mali | 15 | 46 | 8 | 6 | 18 | 3 |
| Mauritania | 84 | 80 | 85 | X | 5 | X |
| Mauritius | 99 | 100 | 98 | 95 | 100 | 90 |
| Morocco | X | 100 | X | X | X | X |
| Mozambique | X | X | X | X | X | X |
| Niger | 34 | 41 | 33 | 7 | 36 | 3 |
| Nigeria | 36 | 60 | 30 | X | 30 | X |
| Rwanda | 60 | 55 | 60 | 60 | 60 | 60 |
| Senegal | 45 | 77 | 25 | 39 | 100 | 2 |
| Sierra Leone | 19 | 61 | 6 | 20 | 52 | 10 |
| Somalia | 34 | 65 | 21 | 18 | 48 | 5 |
| South Africa | X | X | X | X | X | X |
| Sudan | 48 | 100 | 31 | X | 73 | X |
| Swaziland | X | X | X | X | X | X |
| Tanzania, United Rep | 45 | 88 | 39 | 51 | 83 | 47 |
| Togo | 33 | 68 | 26 | 11 | 24 | 8 |
| Tunisia | 60 | 100 | 17 | X | 100 | X |
| Uganda | 16 | 45 | 12 | 13 | 34 | 10 |
| Zaire | 20 | 43 | 5 | 6 | X | 10 |
| Zambia | 47 | 65 | 33 | 70 | 100 | 48 |
| Zimbabwe | X | X | X | X | X | X |
| **NORTH AMERICA** | | | | | | |
| Barbados | 51 | 100 | 18 | X | 1 | X |
| Canada | X | X | X | X | X | X |
| Costa Rica | 82 | 100 | 68 | 87 | 93 | 82 |
| Cuba | X | X | X | X | X | X |
| Dominican Rep | 59 | 85 | 32 | 25 | 41 | 9 |
| El Salvador | 51 | 67 | 40 | 48 | 80 | 26 |
| Guatemala | 51 | 90 | 26 | 36 | 48 | 28 |
| Haiti | 33 | 58 | 25 | 19 | 41 | 12 |
| Honduras | 68 | 91 | 55 | 44 | 50 | 40 |
| Jamaica | X | X | X | X | X | X |
| Mexico | 74 | 91 | 40 | 56 | 78 | 12 |
| Nicaragua | 55 | 91 | 10 | 19 | 35 | X |
| Panama | 83 | 100 | 65 | 45 | 62 | 28 |
| Trinidad and Tobago | 97 | 100 | 96 | 97 | 100 | 96 |
| United States | X | X | X | X | X | X |
| **SOUTH AMERICA** | | | | | | |
| Argentina | 62 | 72 | 17 | 83 | 94 | 32 |
| Bolivia | 40 | 78 | 12 | 22 | 40 | 9 |
| Brazil | 75 | 86 | 53 | X | 33 | X |
| Chile | 85 | 100 | 18 | 82 | 100 | 4 |
| Colombia | 92 | 100 | 79 | 66 | 100 | 4 |
| Ecuador | 55 | 98 | 21 | 43 | 64 | 26 |
| Guyana | 72 | 100 | 60 | 86 | 100 | 80 |
| Paraguay | 24 | 46 | 10 | 87 | 92 | 84 |
| Peru | 53 | 73 | 18 | 37 | 57 | 1 |
| Suriname | 98 | 100 | 96 | 98 | 100 | 96 |
| Uruguay | 81 | 96 | 2 | 59 | 59 | 60 |
| Venezuela | 84 | 91 | 50 | 87 | 90 | 70 |

# Table 3.2

| | Percentage of Population with Access to Safe Drinking Water | | | Percentage of Population with Access to Sanitation Services | | |
|---|---|---|---|---|---|---|
| | Total | Urban | Rural | Total | Urban | Rural |
| **ASIA** | | | | | | |
| Afghanistan | 21 | 39 | 18 | X | 3 | X |
| Bahrain | 100 | 100 | 100 | 100 | 100 | 100 |
| Bangladesh | 42 | 29 | 43 | 4 | 21 | 2 |
| Bhutan | 15 | 40 | 14 | X | X | X |
| Burma | 25 | 36 | 21 | 20 | 34 | 15 |
| China | X | X | X | X | X | X |
| Cyprus | 100 | 100 | 100 | 100 | 100 | 100 |
| India | 55 | 80 | 47 | 8 | 30 | 1 |
| Indonesia | 31 | 40 | 29 | 30 | 31 | 30 |
| Iran | 66 | 82 | 50 | 70 | 96 | 43 |
| Iraq | 82 | 100 | 46 | 71 | 100 | 15 |
| Israel | X | X | X | X | X | X |
| Japan | X | X | X | X | X | X |
| Jordan | 86 | 100 | 65 | 70 | 94 | 34 |
| Kampuchea, Dem | X | X | X | X | X | X |
| Korea, Dem People's Rep | X | X | X | X | X | X |
| Korea, Rep | 75 | 86 | 61 | 100 | 100 | 100 |
| Kuwait | X | X | X | X | X | X |
| Lao People's Dem Rep | 21 | 28 | 20 | 5 | 13 | 4 |
| Lebanon | X | X | X | X | X | X |
| Malaysia | 79 | 97 | 71 | 71 | 100 | 59 |
| Mongolia | X | X | X | X | X | X |
| Nepal | 14 | 71 | 11 | 2 | 16 | 1 |
| Oman | 22 | 100 | 16 | 19 | 100 | 13 |
| Pakistan | 39 | 78 | 24 | 19 | 53 | 6 |
| Philippines | 54 | 53 | 55 | 57 | 75 | 47 |
| Qatar | 71 | 75 | 43 | X | X | X |
| Saudi Arabia | 89 | 100 | 68 | 78 | 100 | 33 |
| Singapore | 100 | 100 | NA | 74 | 100 | NA |
| Sri Lanka | 28 | 65 | 18 | 67 | 80 | 63 |
| Syrian Arab Rep | 79 | 100 | 61 | 47 | 66 | 29 |
| Thailand | 67 | 50 | 70 | 45 | 50 | 44 |
| Turkey | 77 | 95 | 62 | 25 | 56 | X |
| United Arab Emirates | 92 | 95 | 81 | 80 | 93 | 22 |
| Viet Nam | X | X | 31 | X | X | 70 |
| Yemen | 33 | 100 | 21 | X | 75 | X |
| Yemen, Dem | 52 | 73 | 39 | 46 | 69 | 33 |
| **EUROPE** | | | | | | |
| Albania | X | X | X | X | X | X |
| Austria | X | X | X | X | X | X |
| Belgium | X | X | X | X | X | X |
| Bulgaria | X | X | X | X | X | X |
| Czechoslovakia | X | X | X | X | X | X |
| Denmark | X | X | X | X | X | X |
| Finland | X | X | X | X | X | X |
| France | X | X | X | X | X | X |
| German Dem Rep | X | X | X | X | X | X |
| Germany, Fed Rep | X | X | X | X | X | X |
| Greece | X | X | X | X | X | X |
| Hungary | X | X | X | X | X | X |
| Ireland | X | X | X | X | X | X |
| Italy | X | X | X | X | X | X |
| Luxembourg | X | X | X | X | X | X |
| Malta | 100 | 100 | 100 | 97 | 100 | 84 |
| Netherlands | X | X | X | X | X | X |
| Norway | X | X | X | X | X | X |
| Poland | X | X | X | X | X | X |
| Portugal | X | X | X | X | X | X |
| Romania | X | X | X | X | X | X |
| Spain | X | X | X | X | X | X |
| Sweden | X | X | X | X | X | X |
| Switzerland | X | X | X | X | X | X |
| United Kingdom | X | X | X | X | X | X |
| Yugoslavia | X | X | X | X | X | X |
| **USSR** | X | X | X | X | X | X |
| **OCEANIA** | | | | | | |
| Australia | X | X | X | X | X | X |
| Fiji | 77 | 94 | 66 | 70 | 85 | 60 |
| New Zealand | X | X | X | X | X | X |
| Papua New Guinea | 16 | 55 | 10 | 14 | 91 | 3 |
| Solomon Islands | 50 | 96 | 45 | 26 | 80 | 21 |
| **ANTARCTICA** | | | | | | |

**Source:** World Health Organization.
NA = not applicable; X = not available.
*For additional information, see Sources and Technical Notes.*

# Table 3.3 POPULATION OF THE WORLD'S 25 LARGEST URBAN AGGLOMERATIONS, 1985

| Rank | | 1985 Population (millions) | Average Annual Percentage Change 1950–60 | 1960–70 | 1970–80 | 1980–85 | Total Change 1950–85 (percent) |
|---|---|---|---|---|---|---|---|
| 1 | Mexico City, Mexico | 18.1 | 5.3 | 5.9 | 5.0 | 3.8 | 484 |
| 2 | Tokyo/Yokohama, Japan | 17.2 | 4.8 | 3.4 | 1.3 | 0.2 | 157 |
| 3 | São Paulo, Brazil | 15.9 | 5.8 | 5.4 | 4.4 | 4.4 | 468 |
| 4 | New York/Northeastern New Jersey, United States | 15.3 | 1.4 | 1.4 | -0.4 | -0.4 | 23 |
| 5 | Shanghai, China | 11.8 | 0.4 | 0.6 | 0.3 | 0.0 | 15 |
| 6 | Calcutta, India | 11.0 | 2.3 | 2.6 | 3.0 | 3.0 | 150 |
| 7 | Greater Buenos Aires, Argentina | 10.9 | 2.8 | 2.0 | 1.7 | 1.5 | 106 |
| 8 | Rio de Janeiro, Brazil | 10.4 | 3.8 | 3.5 | 2.5 | 2.5 | 197 |
| 9 | Seoul, Rep of Korea | 10.2 | 8.1 | 8.4 | 4.6 | 3.7 | 827 |
| 10 | Greater Bombay, India | 10.1 | 3.3 | 4.0 | 3.7 | 3.5 | 248 |
| 11 | Los Angeles/Long Beach, United States | 10.0 | 4.9 | 2.4 | 1.2 | 1.0 | 144 |
| 12 | London, United Kingdom | 9.8 | 0.3 | -0.1 | -0.6 | -0.4 | -6 |
| 13 | Beijing, China | 9.2 | 0.9 | 1.3 | 0.9 | 0.2 | 37 |
| 14 | Rhein-Ruhr, Fed Rep of Germany | 9.2 | 2.3 | 0.7 | 0.0 | -0.2 | 33 |
| 15 | Paris, France | 8.9 | 2.7 | 1.4 | 0.6 | 0.2 | 62 |
| 16 | Moscow, USSR | 8.7 | 2.8 | 1.2 | 1.5 | 1.2 | 81 |
| 17 | Cairo/Giza/Imbaba, Egypt | 8.5 | 4.0 | 3.9 | 3.1 | 3.1 | 240 |
| 18 | Osaka/Kobe, Japan | 8.0 | 4.1 | 2.9 | 0.5 | 0.0 | 111 |
| 19 | Jakarta, Indonesia | 7.9 | 4.5 | 4.9 | 4.1 | 3.3 | 339 |
| 20 | Tianjin, China | 7.8 | 1.1 | 1.4 | 1.1 | 0.3 | 44 |
| 21 | Delhi, India | 7.4 | 5.1 | 4.6 | 5.1 | 4.6 | 429 |
| 22 | Baghdad, Iraq | 7.2 | 5.2 | 9.6 | 8.6 | 4.8 | 1100 |
| 23 | Teheran, Iran | 7.2 | 7.2 | 6.2 | 5.4 | 5.2 | 700 |
| 24 | Manila, Philippines | 7.0 | 3.7 | 4.6 | 5.2 | 3.1 | 338 |
| 25 | Milan, Italy | 7.0 | 2.3 | 2.2 | 1.7 | 1.2 | 94 |
| **Total — 25 Cities** | | **254.7** | **2.7** | **2.6** | **2.1** | **1.8** | **126** |
| **World Population** | | **4842.0** | **1.9** | **2.0** | **1.9** | **1.7** | **93** |
| **Largest 25 Cities as Percentage of World Total** | | **5.3** | | | | | |

**Source:** U.N. Department of International Economic and Social Affairs.
0 = zero or less than one-half the unit of measure.
For additional information, see Sources and Technical Notes.

# Table 3.4 WASTE GENERATION IN SELECTED COUNTRIES, 1980

| | Municipal Waste Generation: Total (thousand metric tons per year) | Municipal Waste Generation: Kilograms per Capita per Year | Industrial Waste Generation: Total (thousand metric tons per year) | Industrial Waste Generation: Metric Tons per Million $US of Industrial Gross Domestic Product | Hazardous and Special Wastes (thousand metric tons per year) |
|---|---|---|---|---|---|
| Australia | 10000 | 681 | 20000 | X | X |
| Austria | 1560 | 208 | 300 | 10 | 100 |
| Belgium | 3082 | 313 | 8000 | 186 | 915 |
| Canada | 12600 | 526 | 61000 | 730 | 3290 |
| Denmark | 2046 | 399 | 814 | X | 63 |
| Finland | 1200 | 290 | X | X | 87 |
| France | 15500 | 289 | 38205 | 163 | 2000 |
| Germany, Fed Rep | 20780 | 338 | 52469 | X | 4892 |
| Greece | 2500 | 259 | X | X | X |
| Ireland | 640 | 188 | 1200 | X | X |
| Italy | 14041 | 246 | 35000 | 207 | X |
| Japan | 40225 | 344 | 161677 | 379 | 768 |
| Netherlands | 5400 | 382 | 4869 | 79 | 280 |
| New Zealand | 1528 | 488 | 498 | 67 | X |
| Norway | 1700 | 415 | 2186 | 93 | 120 |
| Portugal | 1500 | 152 | 11200 | 1110 | X |
| Spain | 8028 | 215 | X | X | X |
| Sweden | 2500 | 301 | 4000 | 102 | 550 |
| Switzerland | 2146 | 337 | X | X | 100 |
| United Kingdom | 15816 | 282 | 89749 | 490 | 1500 |
| United States | 160000 | 703 | 400000 | 455 | 264000 |

**Source:** Organization for Economic Cooperation and Development.
X = not available.
**Note:** Industrial Gross Domestic Product is the portion of Gross Domestic Product contributed by industry.
For additional information, see Sources and Technical Notes.

# Sources and Technical Notes

## Table 3.1 Population Distribution, 1960–85

**Sources:** Urban population and average annual growth rate: U.N. Department of International Economic and Social Affairs (UNDIESA), *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985). Population living in cities over 100,000: World Bank, *World Development Report 1985* (Oxford University Press, New York, 1985).

Urban population is defined as the portion of the total population residing in urban areas. The remainder of the population is defined as rural. However, the definition of urban area varies widely from country to country. (See Part II, Chapter 3, "Human Settlements," Box 3.1.) For a list of individual country definitions, see UNDIESA *Estimates and Projections of Urban, Rural, and City Populations, 1950–2025: The 1982 Assessment* (United Nations, New York, 1985).

The definition of a city with over 100,000 population also varies from country to country. Most national censuses collect population data on one of three settlement patterns: the urban agglomeration, the metropolitan area, or the city proper. The United Nations uses data for the urban agglomeration when available. An urban agglomeration is defined as the population contained within the contours of the contiguous territory inhabited at urban levels of residential density without regard to administrative boundaries. The metropolitan area includes the urban agglomeration as well as surrounding areas of lower population density. If neither of these is available, the city proper definition is used; this tends to underestimate the population. For additional information on methods of data collection and estimation, refer to the Technical Notes for Table 2.1 in Chapter 2 "Population and Health."

## Table 3.2 Drinking Water and Sanitation, Early 1980s

**Sources:** World Health Organization (WHO), *The International Drinking Water Supply and Sanitation Decade Review of National Baseline Data: December 1980* (WHO, Geneva, 1984); and draft tables from *The International Drinking Water Supply and Sanitation Decade: Review of National Baseline Data: December 1983* (WHO, Geneva, in press, 1986).

Data were collected from national governments by the World Health Organization (WHO) in 1980 and again in 1983 by means of questionnaires. The questionnaires were answered by public health officials, WHO experts, and Resident Representatives of the United Nations Development Program. The data collection effort was used to develop baseline information with which to assess progress in meeting national goals set for the International Drinking Water Supply and Sanitation Decade. Ninety-three of the 113 developing countries shown in Table 3.2 responded to either the 1980 or the 1983 questionnaire. These countries represented about 94 percent of the population of the developing world, excluding China. This total included 37 countries in Africa, covering 78 percent of the population (excluding South Africa); 23 countries in the Americas, covering 97 percent of the developing country population; and 29 countries in Asia, covering 98 percent of the population, excluding China. The next round of data collection is set for 1986.

The definitions of urban and rural population were supplied by national governments. (See Notes to Table 3.1.)

The WHO defines reasonable access to safe drinking water in an urban area as piped water to a housing unit or to a public standpipe within 200 meters. In rural areas, reasonable access implies that a family member need not spend a disproportionate part of the day fetching water. "Safe" drinking water includes treated surface water and untreated water from protected springs, boreholes, and sanitary wells. Other sources are considered unsafe.

Urban areas with access to sanitation services were defined as urban populations served by connections to public sewers or household systems such as pit privies, pour-flush latrines, septic tanks, communal toilets, etc. Rural populations with access had adequate disposal such as pit privies, pour-flush latrines, etc.

The application of these definitions to the situation in a country is clearly open to a considerable degree of subjective judgement. Comparisons between countries may therefore be misleading because of varied interpretations of definitions as well as incomplete responses. WHO reports note that access to sanitation in rural areas is systematically under-reported; no alternative estimates have been provided.

## Table 3.3 Population of the World's 25 Largest Urban Agglomerations, 1985

**Sources:** U.N. Department for International Economic and Social Affairs, *Estimates and Projections of Urban, Rural and City Populations, 1950–2025: The 1982 Assessment* (United Nations, New York, 1985), Tables A-12 and A-13, pp. 144–148.

The 25 largest cities are large urban agglomerations, composed, in most cases, of the central city, adjacent smaller cities and towns, and suburbs. City boundaries depend on local administrative boundaries, population densities, types of economic activity, and other characteristics. Rankings depend on the population living within the urban agglomeration boundaries as determined by local and national governments. Rankings would not necessarily be the same if uniform criteria were used. The estimates for the Chinese cities–Shanghai and Beijing–should be considered tentative. Results of the 1982 Chinese Census may lead to substantial revisions. Average annual percent changes were calculated using the compound growth formula.

## Table 3.4 Waste Generation in Selected Countries, 1980

**Sources:** Waste data: Organization for Economic Co-operation and Development (OECD), *Environmental Data Compendium 1985* (OECD, Paris, 1985), pp. 147 and 153. Gross Domestic Product data: The World Bank, *World Development Report 1982* (Oxford University Press, New York, 1982), Table 2, p. 112.

Municipal waste is composed of trash collected from households, commercial establishments, and small industries. It includes refuse from markets and gardens if collected and disposed of by the municipality. Paper, cardboard, and plastic packaging comprise 25–50 percent of municipal waste, depending on local consumption and production patterns. Other municipal wastes include organic matter, metals, leather, textiles, wood, and rubber.

Industrial waste comprises chemical and non-chemical wastes. Amounts of industrial waste depend on the levels of industrial production, types of technology used, and the definition of waste used in the country.

Hazardous waste is that waste known to contain potentially harmful substances. (Nuclear wastes are not included in this table. See Table 8.3.)

Additional caveats concerning national waste estimates are as follows:

1. New Zealand—municipal waste includes demolition waste; industrial waste is non-chemical waste only.
2. Australia—special and hazardous wastes are included under industrial waste.
3. Netherlands — industrial waste covers that from enterprises that employ ten or more people only and includes office and canteen wastes; hazardous waste refers to "notifiable" wastes only.
4. Norway—industrial waste includes chemical waste only.
5. United Kingdom—industrial waste includes some agricultural wastes.
6. Canada—hazardous waste is measured in wet weight.
7. Denmark — includes only hazardous waste that has been legally disposed of.
8. France—hazardous waste is toxic or hazardous waste.

For a more detailed discussion of hazardous waste measurement in the United States, see *State of the Environment: An Assessment At Mid-Decade* (The Conservation Foundation, Washington, D.C., 1984) pp. 68–73.

# 4. Land Use and Cover

The tables in this section are intended to provide a global picture of land cover, land use, and natural disasters caused by land disturbances. Data with which to examine specific kinds of land use and cover in more detail are shown in the sections on food and agriculture, forests and rangeland, wildlife resources, oceans and coasts, and human settlements.

Data on land use, collected by the U.N. Food and Agriculture Organization (FAO), are shown in Table 4.1. They highlight country and regional changes in agriculture, forestry, and range management over the last 10 to 20 years. Because the FAO is principally concerned with the production of crops, forest products, and livestock, it classifies the rest of a country's land as "Other Land," which includes wetlands, tundra, deserts, cities and towns, roadways and transport facilities, and all other unclassified land. The table, therefore, cannot be used to analyze changes in settlement patterns, parks and protected areas, industry, energy and transport facilities, or other uses.

The statistics on percentage distribution show a picture of changing patterns of land use over the past 15 to 20 years. In 1983, Africa had about 6 percent of its total land area in arable and permanent cropland; the figure was 5 percent in 1965. This change represents roughly a 20 percent increase over the past 18 years. Of the 49 African countries shown in the table, 41 reported increases in arable and permanent cropland, with 12 having increases greater than 25 percent.

Changes in land use are net changes. In the United States, for example, bottomland-hardwood forest along the Mississippi River has been drained and planted with soybeans, while marginal cropland in the Northeast and Midwest has returned to woodland and forest. The total amount of arable and permanent cropland remains about the same, but different kinds of land are now under cultivation than in the 1950s.

The FAO depends principally on figures supplied by national governments. When governments do not provide figures, the FAO develops estimates from unofficial sources, other international organizations, and their own best judgements. Preparing these estimates on an annual basis is not easy. Short-term changes (one to five years) in land use are generally very poorly monitored at the national level. In its most recent *Production Yearbook*, for example, the FAO had to provide its own estimates of agricultural land use for all African countries. When countries report a rapidly growing population over an 18-year period, but no change in land use, the statistics are probably unreliable.

The FAO's baseline information on land use for most countries is drawn from the World Census of Agriculture. About every ten years, countries collect extensive data on agricultural land use, tenure, and holdings using classifications and methods designed by the FAO. With the completion of the 1980 Census—the results of 31 countries had been published as of May 1985—national governments and the FAO will be better able to estimate the extent of and changes in major land uses.

With the increasing availability of data from remote sensors on satellites and other platforms, broad structural changes in vegetative cover and land use (forests to grasslands, for example) can be monitored more precisely. This information will not replace the need for on-the-ground measurements; however, it will help analysts improve the identification of land suitable (and unsuitable) for cultivation, monitor the extent of settlements, identify areas of rapid deforestation, and more.

Table 4.2 provides statistics on the current extent and type of vegetation and the patterns of vegetation that prevailed before the widespread establishment of agriculture and urban centers. These data can be used to analyze long-term changes in forest and grassland and can be compared with changes in cultivated area.

Important land disturbances include earthquakes, volcanoes, land subsidence, and mud slides. With the rapid improvement in seismology and remote sensing, virtually all significant earthquakes and active volcanoes are known and many smaller earthquakes are recorded. Although there is a noticeable decline in the number of deaths from major earthquakes in a few regions, the overall totals still reflect the devastation of a few major events, such as the 1976 earthquake in Tangshan, China, that killed 240,000 people.

# Table 4.1 LAND USE, 1964–85

| | Area (thousand square kilometers) | | | Population Density (persons per square kilometer of total area) | Percentage Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Arable Land and Permanent Cropland | | Meadows and Permanent Pasture | | Forests and Woodland | | Other Land | |
| | Total | Land | Inland Water | 1985 | 1964-66 | 1981-83 | 1964-66 | 1981-83 | 1964-66 | 1981-83 | 1964-66 | 1981-83 |
| **WORLD** | **147922** | **144774** | **3148** | **36.2** | **10** | **11** | **24** | **24** | **33** | **31** | **33** | **33** |
| **AFRICA** | **30331** | **29664** | **667** | **18.2** | **5** | **6** | **26** | **26** | **25** | **23** | **43** | **44** |
| Algeria | 2382 | 2382 | 0 | 9.2 | 3 | 3 | 16 | 14 | 1 | 2 | 80 | 81 |
| Angola | 1247 | 1247 | 0 | 7.0 | 3 | 3 | 23 | 23 | 44 | 43 | 30 | 31 |
| Benin | 113 | 111 | 2 | 35.6 | 13 | 16 | 4 | 4 | 44 | 35 | 39 | 45 |
| Botswana | 600 | 585 | 15 | 1.8 | 2 | 2 | 71 | 75 | 2 | 2 | 26 | 21 |
| Burkina Faso | 274 | 274 | 0 | 25.3 | 8 | 10 | 37 | 37 | 30 | 26 | 26 | 28 |
| Burundi | 28 | 26 | 2 | 166.4 | 39 | 51 | 25 | 36 | 2 | 2 | 35 | 11 |
| Cameroon | 475 | 469 | 6 | 20.4 | 12 | 15 | 19 | 18 | 58 | 54 | 11 | 13 |
| Cape Verde | 4 | 4 | 0 | 79.7 | 10 | 10 | 6 | 6 | 0 | 0 | 84 | 84 |
| Central African Rep | 623 | 623 | 0 | 4.1 | 3 | 3 | 5 | 5 | 64 | 64 | 28 | 28 |
| Chad | 1284 | 1259 | 25 | 3.9 | 2 | 3 | 36 | 36 | 17 | 16 | 45 | 46 |
| Comoros | 2 | 2 | 0 | 210.6 | 39 | 42 | 7 | 7 | 16 | 16 | 38 | 35 |
| Congo | 342 | 342 | 1 | 5.1 | 2 | 2 | 29 | 29 | 64 | 62 | 5 | 6 |
| Djibouti | 22 | 22 | 0 | 13.3 | 0 | 0 | 9 | 9 | 0 | 0 | 91 | 91 |
| Egypt | 1001 | 995 | 6 | 46.7 | 3 | 2 | 0 | 0 | 0 | 0 | 97 | 98 |
| Equatorial Guinea | 28 | 28 | 0 | 14.0 | 8 | 8 | 4 | 4 | 61 | 61 | 28 | 27 |
| Ethiopia | 1222 | 1101 | 121 | 29.8 | 11 | 13 | 42 | 41 | 27 | 24 | 20 | 22 |
| Gabon | 268 | 258 | 10 | 4.4 | 1 | 2 | 20 | 18 | 78 | 78 | 2 | 2 |
| Gambia | 11 | 10 | 1 | 56.9 | 13 | 16 | 9 | 9 | 30 | 20 | 48 | 55 |
| Ghana | 239 | 230 | 9 | 56.5 | 11 | 12 | 16 | 15 | 43 | 38 | 30 | 35 |
| Guinea | 246 | 246 | 0 | 22.1 | 6 | 6 | 12 | 12 | 49 | 43 | 33 | 39 |
| Guinea-Bissau | 36 | 28 | 8 | 24.6 | 9 | 10 | 46 | 46 | 39 | 38 | 6 | 6 |
| Ivory Coast | 322 | 318 | 4 | 30.4 | 8 | 12 | 9 | 9 | 60 | 28 | 22 | 50 |
| Kenya | 583 | 569 | 13 | 35.4 | 3 | 4 | 7 | 7 | 5 | 4 | 85 | 85 |
| Lesotho | 30 | 30 | 0 | 50.1 | 12 | 10 | 73 | 66 | 0 | 0 | 15 | 24 |
| Liberia | 111 | 96 | 15 | 19.7 | 4 | 4 | 2 | 2 | 40 | 39 | 54 | 55 |
| Libya | 1760 | 1760 | 0 | 2.0 | 1 | 1 | 6 | 8 | 0 | 0 | 93 | 91 |
| Madagascar | 587 | 582 | 6 | 17.1 | 4 | 5 | 58 | 58 | 27 | 23 | 10 | 14 |
| Malawi | 118 | 94 | 24 | 59.2 | 21 | 25 | 20 | 20 | 53 | 45 | 6 | 10 |
| Mali | 1240 | 1220 | 20 | 6.5 | 1 | 2 | 25 | 25 | 8 | 7 | 66 | 67 |
| Mauritania | 1031 | 1030 | 0 | 1.8 | 0 | 0 | 38 | 38 | 15 | 15 | 47 | 47 |
| Mauritius | 2 | 2 | 0 | 564.5 | 50 | 58 | 4 | 4 | 33 | 31 | 13 | 7 |
| Morocco | 447 | 446 | 0 | 52.9 | 16 | 19 | 28 | 28 | 12 | 12 | 44 | 42 |
| Mozambique | 802 | 784 | 18 | 17.6 | 3 | 4 | 56 | 56 | 22 | 19 | 18 | 21 |
| Niger | 1267 | 1267 | 0 | 4.8 | 2 | 3 | 8 | 7 | 3 | 2 | 87 | 88 |
| Nigeria | 924 | 911 | 13 | 103.1 | 32 | 33 | 21 | 23 | 21 | 16 | 26 | 28 |
| Rwanda | 26 | 25 | 1 | 232.2 | 26 | 41 | 34 | 18 | 13 | 11 | 27 | 31 |
| Senegal | 196 | 192 | 4 | 33.2 | 23 | 27 | 30 | 30 | 35 | 30 | 12 | 13 |
| Sierra Leone | 72 | 72 | 0 | 50.2 | 20 | 25 | 31 | 31 | 29 | 29 | 20 | 16 |
| Somalia | 638 | 627 | 10 | 8.7 | 2 | 2 | 46 | 46 | 15 | 14 | 37 | 38 |
| South Africa | 1221 | 1221 | 0 | 26.5 | 11 | 11 | 69 | 66 | 4 | 4 | 16 | 20 |
| Sudan | 2506 | 2376 | 130 | 8.6 | 5 | 5 | 24 | 24 | 24 | 20 | 47 | 51 |
| Swaziland | 17 | 17 | 0 | 37.4 | 8 | 8 | 78 | 67 | 8 | 6 | 6 | 19 |
| Tanzania, United Rep | 945 | 886 | 59 | 23.8 | 4 | 6 | 40 | 40 | 50 | 47 | 7 | 7 |
| Togo | 57 | 54 | 2 | 51.5 | 21 | 26 | 4 | 4 | 45 | 29 | 31 | 41 |
| Tunisia | 164 | 155 | 8 | 44.1 | 28 | 31 | 16 | 20 | 3 | 4 | 53 | 46 |
| Uganda | 236 | 200 | 36 | 66.5 | 24 | 30 | 25 | 25 | 32 | 30 | 19 | 15 |
| Zaire | 2345 | 2268 | 78 | 14.1 | 3 | 3 | 4 | 4 | 80 | 78 | 13 | 15 |
| Zambia | 753 | 741 | 12 | 8.9 | 7 | 7 | 47 | 47 | 30 | 27 | 17 | 18 |
| Zimbabwe | 391 | 387 | 4 | 22.4 | 5 | 7 | 13 | 13 | 62 | 62 | 20 | 19 |
| **NORTH AMERICA** | **22415** | **21356** | **1059** | **17.9** | **12** | **13** | **17** | **17** | **33** | **32** | **38** | **39** |
| Barbados | 0 | 0 | 0 | 616.3 | 77 | 77 | 9 | 9 | 0 | 0 | 14 | 14 |
| Canada | 9976 | 9221 | 755 | 2.6 | 4 | 5 | 2 | 3 | 34 | 35 | 59 | 57 |
| Costa Rica | 51 | 51 | 0 | 51.3 | 10 | 12 | 21 | 42 | 58 | 33 | 11 | 13 |
| Cuba | 115 | 115 | 0 | 87.7 | 17 | 29 | 25 | 22 | 14 | 17 | 45 | 32 |
| Dominican Rep | 49 | 48 | 0 | 128.1 | 22 | 30 | 43 | 43 | 14 | 13 | 21 | 14 |
| El Salvador | 21 | 21 | 0 | 263.9 | 32 | 35 | 29 | 29 | 9 | 6 | 30 | 29 |
| Guatemala | 109 | 108 | 0 | 77.2 | 14 | 16 | 12 | 12 | 48 | 40 | 26 | 31 |
| Haiti | 28 | 28 | 0 | 237.3 | 22 | 33 | 18 | 18 | 3 | 4 | 57 | 46 |
| Honduras | 112 | 112 | 0 | 39.0 | 13 | 16 | 30 | 30 | 47 | 35 | 9 | 19 |
| Jamaica | 11 | 11 | 0 | 211.4 | 25 | 25 | 22 | 19 | 28 | 28 | 24 | 29 |
| Mexico | 1973 | 1923 | 50 | 40.0 | 12 | 12 | 39 | 39 | 29 | 25 | 20 | 24 |
| Nicaragua | 130 | 119 | 11 | 25.2 | 10 | 11 | 35 | 42 | 52 | 36 | 3 | 11 |
| Panama | 77 | 76 | 1 | 28.3 | 7 | 8 | 14 | 15 | 61 | 54 | 18 | 23 |
| Trinidad and Tobago | 5 | 5 | 0 | 217.9 | 27 | 31 | 1 | 2 | 48 | 44 | 24 | 23 |
| United States | 9363 | 9127 | 236 | 25.4 | 20 | 21 | 28 | 26 | 32 | 30 | 20 | 23 |
| **SOUTH AMERICA** | **17819** | **17535** | **284** | **15.1** | **6** | **8** | **24** | **26** | **57** | **53** | **13** | **13** |
| Argentina | 2767 | 2737 | 30 | 11.0 | 11 | 13 | 53 | 52 | 22 | 22 | 14 | 13 |
| Bolivia | 1099 | 1084 | 14 | 5.8 | 2 | 3 | 26 | 25 | 55 | 52 | 18 | 20 |
| Brazil | 8512 | 8457 | 55 | 15.9 | 6 | 9 | 15 | 19 | 71 | 67 | 8 | 5 |
| Chile | 757 | 749 | 8 | 16.0 | 6 | 7 | 14 | 16 | 21 | 21 | 60 | 56 |
| Colombia | 1139 | 1039 | 100 | 25.2 | 5 | 5 | 29 | 29 | 63 | 50 | 4 | 16 |
| Ecuador | 284 | 277 | 7 | 33.1 | 9 | 9 | 8 | 15 | 62 | 52 | 21 | 24 |
| Guyana | 215 | 197 | 18 | 4.4 | 2 | 3 | 5 | 6 | 92 | 83 | 1 | 8 |
| Paraguay | 407 | 397 | 9 | 9.0 | 2 | 5 | 35 | 39 | 54 | 52 | 9 | 4 |
| Peru | 1285 | 1280 | 5 | 15.3 | 2 | 3 | 21 | 21 | 58 | 55 | 18 | 21 |
| Suriname | 163 | 161 | 2 | 2.2 | 0 | 0 | 0 | 0 | 96 | 96 | 3 | 3 |
| Uruguay | 176 | 174 | 3 | 17.1 | 8 | 8 | 79 | 79 | 3 | 4 | 9 | 10 |
| Venezuela | 912 | 882 | 30 | 20.2 | 4 | 4 | 18 | 20 | 45 | 39 | 33 | 37 |

# Table 4.1

| | Area (thousand square kilometers) | | | Population Density (persons per square kilometer of total area) | Percentage Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Arable Land and Permanent Cropland | | Meadows and Permanent Pasture | | Forests and Woodland | | Other Land | |
| | Total | Land | Inland Water | 1985 | 1964-66 | 1981-83 | 1964-66 | 1981-83 | 1964-66 | 1981-83 | 1964-66 | 1981–83 |
| **ASIA** | **27575** | **26791** | **784** | **102.4** | **16** | **17** | **25** | **24** | **21** | **21** | **38** | **38** |
| Afghanistan | 648 | 648 | 0 | 22.6 | 12 | 12 | 46 | 46 | 3 | 3 | 38 | 38 |
| Bahrain | 1 | 1 | 0 | 695.2 | 3 | 3 | 6 | 6 | 0 | 0 | 90 | 90 |
| Bangladesh | 144 | 134 | 10 | 702.4 | 67 | 68 | 4 | 4 | 17 | 16 | 12 | 11 |
| Bhutan | 47 | 47 | 0 | 30.1 | 1 | 2 | 4 | 5 | 66 | 70 | 28 | 24 |
| Burma | 677 | 658 | 19 | 58.4 | 16 | 15 | 1 | 1 | 49 | 49 | 35 | 35 |
| China | 9597 | 9326 | 271 | 110.8 | 11 | 11 | 31 | 31 | 11 | 14 | 47 | 45 |
| Cyprus | 9 | 9 | 0 | 72.1 | 47 | 47 | 10 | 10 | 19 | 19 | 25 | 25 |
| India | 3288 | 2973 | 314 | 231.5 | 55 | 57 | 5 | 4 | 20 | 23 | 20 | 17 |
| Indonesia | 1905 | 1812 | 93 | 86.6 | 10 | 11 | 7 | 7 | 68 | 67 | 15 | 15 |
| Iran | 1648 | 1636 | 12 | 27.4 | 9 | 8 | 27 | 27 | 11 | 11 | 53 | 54 |
| Iraq | 435 | 434 | 1 | 36.0 | 11 | 13 | 9 | 9 | 4 | 3 | 75 | 75 |
| Israel | 21 | 20 | 0 | 206.9 | 20 | 21 | 40 | 40 | 5 | 6 | 35 | 33 |
| Japan | 372 | 371 | 1 | 322.5 | 16 | 13 | 0 | 2 | 69 | 68 | 15 | 17 |
| Jordan | 98 | 97 | 1 | 35.9 | 4 | 4 | 1 | 1 | 0 | 0 | 95 | 94 |
| Kampuchea, Dem | 181 | 177 | 5 | 40.8 | 16 | 17 | 3 | 3 | 76 | 76 | 5 | 4 |
| Korea, Dem People's Rep | 121 | 120 | 0 | 166.6 | 16 | 19 | 0 | 0 | 74 | 74 | 9 | 6 |
| Korea, Rep | 98 | 98 | 0 | 415.0 | 23 | 22 | 0 | 1 | 68 | 67 | 9 | 11 |
| Kuwait | 18 | 18 | 0 | 100.2 | 0 | 0 | 8 | 8 | 0 | 0 | 92 | 92 |
| Lao People's Dem Rep | 237 | 231 | 6 | 18.7 | 4 | 4 | 3 | 3 | 63 | 55 | 30 | 37 |
| Lebanon | 10 | 10 | 0 | 256.5 | 28 | 29 | 1 | 1 | 9 | 7 | 61 | 63 |
| Malaysia | 330 | 329 | 1 | 47.2 | 11 | 13 | 0 | 0 | 79 | 67 | 10 | 20 |
| Mongolia | 1565 | 1565 | 0 | 1.2 | 1 | 1 | 89 | 79 | 10 | 10 | 1 | 11 |
| Nepal | 141 | 137 | 4 | 117.1 | 13 | 17 | 12 | 13 | 33 | 33 | 41 | 37 |
| Oman | 212 | 212 | 0 | 5.8 | 0 | 0 | 5 | 5 | 0 | 0 | 95 | 95 |
| Pakistan | 804 | 779 | 25 | 126.5 | 25 | 26 | 6 | 6 | 3 | 4 | 66 | 64 |
| Philippines | 300 | 298 | 2 | 182.4 | 31 | 38 | 3 | 4 | 57 | 41 | 10 | 17 |
| Qatar | 11 | 11 | 0 | 27.4 | 0 | 0 | 5 | 5 | 0 | 0 | 95 | 95 |
| Saudi Arabia | 2150 | 2150 | 0 | 5.2 | 0 | 1 | 40 | 40 | 1 | 1 | 59 | 59 |
| Singapore | 1 | 1 | 0 | 4434.5 | 23 | 11 | 0 | 0 | 7 | 5 | 70 | 84 |
| Sri Lanka | 66 | 65 | 1 | 250.0 | 28 | 34 | 4 | 7 | 49 | 37 | 19 | 23 |
| Syrian Arab Rep | 185 | 184 | 1 | 57.1 | 35 | 31 | 42 | 45 | 3 | 3 | 20 | 21 |
| Thailand | 514 | 512 | 2 | 100.3 | 25 | 37 | 1 | 1 | 51 | 31 | 24 | 31 |
| Turkey | 781 | 771 | 10 | 64.0 | 34 | 36 | 14 | 12 | 26 | 26 | 25 | 26 |
| United Arab Emirates | 84 | 84 | 0 | 15.7 | 0 | 0 | 2 | 2 | 0 | 0 | 98 | 97 |
| Viet Nam | 330 | 325 | 4 | 180.4 | 18 | 21 | 1 | 6 | 43 | 38 | 38 | 36 |
| Yemen | 195 | 195 | 0 | 33.6 | 14 | 14 | 36 | 36 | 8 | 8 | 42 | 42 |
| Yemen, Dem | 333 | 333 | 0 | 6.4 | 1 | 1 | 27 | 27 | 8 | 7 | 64 | 65 |
| **EUROPE** | **4871** | **4728** | **143** | **101.0** | **28** | **30** | **20** | **18** | **32** | **33** | **20** | **19** |
| Albania | 29 | 27 | 1 | 106.1 | 19 | 26 | 26 | 20 | 46 | 45 | 9 | 9 |
| Austria | 84 | 83 | 1 | 89.3 | 21 | 19 | 27 | 25 | 38 | 39 | 14 | 17 |
| Belgium | 33 | 33 | 0 | 298.5 | 30 | 25 | 24 | 21 | 21 | 21 | 24 | 33 |
| Bulgaria | 111 | 111 | 0 | 83.1 | 41 | 38 | 11 | 18 | 33 | 35 | 15 | 9 |
| Czechoslovakia | 128 | 125 | 2 | 122.4 | 42 | 41 | 14 | 13 | 35 | 37 | 9 | 9 |
| Denmark | 43 | 42 | 1 | 119.4 | 64 | 62 | 8 | 6 | 11 | 12 | 18 | 20 |
| Finland | 337 | 305 | 32 | 14.5 | 8 | 8 | 0 | 0 | 72 | 76 | 20 | 15 |
| France | 547 | 546 | 1 | 99.8 | 38 | 34 | 25 | 23 | 23 | 27 | 15 | 16 |
| German Dem Rep | 108 | 106 | 2 | 153.6 | 47 | 47 | 14 | 12 | 28 | 28 | 12 | 13 |
| Germany, Fed Rep | 249 | 244 | 4 | 245.8 | 31 | 31 | 22 | 19 | 30 | 30 | 17 | 20 |
| Greece | 132 | 131 | 1 | 75.3 | 29 | 30 | 39 | 40 | 20 | 20 | 12 | 10 |
| Hungary | 93 | 92 | 1 | 116.1 | 61 | 57 | 14 | 14 | 15 | 18 | 9 | 11 |
| Ireland | 103 | 100 | 3 | 34.9 | 18 | 14 | 64 | 70 | 3 | 5 | 15 | 11 |
| Italy | 301 | 294 | 7 | 188.8 | 52 | 42 | 17 | 17 | 21 | 22 | 10 | 19 |
| Luxembourg | X | X | X | X | X | X | X | X | X | X | X | X |
| Malta | 0 | 0 | 0 | 1193.8 | 44 | 44 | 0 | 0 | 0 | 0 | 56 | 56 |
| Netherlands | 37 | 34 | 3 | 388.8 | 29 | 25 | 39 | 34 | 9 | 9 | 24 | 32 |
| Norway | 324 | 308 | 16 | 12.8 | 3 | 3 | 1 | 0 | 23 | 27 | 73 | 70 |
| Poland | 313 | 305 | 8 | 120.1 | 52 | 49 | 14 | 13 | 26 | 29 | 8 | 9 |
| Portugal | 92 | 92 | 0 | 109.4 | 46 | 39 | 6 | 6 | 36 | 40 | 13 | 16 |
| Romania | 238 | 230 | 7 | 97.1 | 46 | 46 | 19 | 19 | 28 | 28 | 8 | 8 |
| Spain | 505 | 499 | 5 | 77.3 | 0 | 41 | 41 | 21 | 45 | 31 | 14 | 6 |
| Sweden | 450 | 412 | 38 | 18.4 | 8 | 7 | 2 | 2 | 64 | 64 | 27 | 27 |
| Switzerland | 41 | 40 | 2 | 152.3 | 10 | 10 | 44 | 40 | 25 | 26 | 21 | 23 |
| United Kingdom | 245 | 242 | 3 | 227.3 | 25 | 29 | 55 | 48 | 8 | 9 | 12 | 14 |
| Yugoslavia | 256 | 255 | 0 | 90.7 | 33 | 31 | 25 | 25 | 34 | 37 | 8 | 8 |
| **USSR** | **22402** | **22272** | **130** | **12.4** | **10** | **10** | **17** | **17** | **41** | **41** | **32** | **32** |
| **OCEANIA** | **8510** | **8429** | **81** | **2.9** | **5** | **6** | **55** | **55** | **22** | **18** | **19** | **21** |
| Australia | 7687 | 7618 | 69 | 2.0 | 5 | 6 | 59 | 59 | 18 | 14 | 18 | 21 |
| Fiji | 18 | 18 | 0 | 37.4 | 11 | 13 | 4 | 3 | 65 | 65 | 20 | 19 |
| New Zealand | 269 | 269 | 0 | 12.2 | 2 | 2 | 48 | 54 | 27 | 37 | 23 | 7 |
| Papua New Guinea | 462 | 452 | 10 | 8.0 | 1 | 1 | 0 | 0 | 72 | 71 | 27 | 28 |
| Solomon Islands | 28 | 28 | 1 | 9.6 | 2 | 2 | 1 | 1 | 93 | 93 | 4 | 4 |
| **ANTARCTICA** | **14000** | **14000** | **0** | | | | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 4.2 LAND USE AND COVER, PREAGRICULTURE TO PRESENT

| | Preagricultural Area (million square kilometers) | Present Area (million square kilometers) | Absolute Amount Converted to Cultivation (million square kilometers) | Percentage Converted to Cultivation |
|---|---|---|---|---|
| **TOTAL ICE-FREE LAND AREA** | **132.51** | **115.05** | **17.46** | **13.00** |
| **FOREST** | **49.86** | **42.10** | **7.76** | **15.56** |
| Tropical evergreen rainforest, mangrove | 12.80 | 12.30 | 0.50 | 4.00 |
| Tropical/subtropical evergreen seasonal broadleaved forest | 4.09 | 3.33 | 0.76 | 19.00 |
| Subtropical evergreen rainforest | 0.22 | 0.19 | 0.03 | 14.00 |
| Temperate/subpolar evergreen rainforest | 0.43 | 0.39 | 0.04 | 9.00 |
| Temperate evergreen seasonal broadleaved forest, summer rain | 1.20 | 0.81 | 0.39 | 32.00 |
| *Evergreen broadleaved sclerophyllous forest, winter rain* | 0.64 | 0.47 | 0.17 | 27.00 |
| Tropical/subtropical evergreen needleleaved forest | 0.53 | 0.50 | 0.03 | 6.00 |
| Temperate/subpolar evergreen needleleaved forest | 9.63 | 9.29 | 0.34 | 4.00 |
| Tropical/subtropical drought-deciduous forest | 3.95 | 2.95 | 1.00 | 25.00 |
| Cold-deciduous forest, with evergreens | 7.75 | 5.18 | 2.57 | 33.00 |
| Cold-deciduous forest, without evergreens | 5.52 | 3.99 | 1.53 | 28.00 |
| Xeromorphic forest/woodland | 3.10 | 2.70 | 0.40 | 13.00 |
| **WOODLAND** | **12.32** | **10.44** | **1.88** | **15.26** |
| Evergreen broadleaved sclerophyllous woodland | 2.33 | 1.71 | 0.62 | 27.00 |
| Evergreen needleleaved woodland | 2.64 | 2.51 | 0.13 | 5.00 |
| Tropical/subtropical drought-deciduous woodland | 4.72 | 3.72 | 1.00 | 21.00 |
| Cold-deciduous woodland | 2.63 | 2.50 | 0.13 | 5.00 |
| **SHRUBLAND** | **13.12** | **12.15** | **0.97** | **7.39** |
| Evergreen needleleaved shrubland/thicket and dwarf shrubland | 1.55 | 1.31 | 0.24 | 15.00 |
| Evergreen needleleaved or microphyllous shrubland/thicket | 0.71 | 0.67 | 0.04 | 6.00 |
| Drought-deciduous shrubland/thicket & dwarf shrubland/thicket | 0.99 | 0.84 | 0.15 | 15.00 |
| Cold-deciduous subalpine/subpolar shrubland and dwarf shrubland | 0.46 | 0.46 | 0.00 | 0.00 |
| Xeromorphic shrubland/dwarf shrubland | 9.41 | 8.87 | 0.54 | 6.00 |
| **TUNDRA** | **7.35** | **7.35** | **0.00** | **0.00** |
| Arctic/alpine tundra, mossy bog | 7.35 | 7.35 | 0.00 | 0.00 |
| **GRASSLAND** | **34.01** | **27.45** | **6.56** | **19.29** |
| Tall/medium/short grassland with 10-40% tree cover | 8.53 | 6.46 | 2.07 | 24.00 |
| Tall/medium/short grassland with less than 10% tree cover or tuft-plant cover | 4.19 | 3.66 | 0.53 | 13.00 |
| Tall/medium/short grassland with shrub cover | 10.72 | 9.35 | 1.37 | 13.00 |
| Tall grassland, no woody cover | 1.46 | 0.81 | 0.65 | 45.00 |
| Medium grassland, no woody cover | 1.49 | 0.79 | 0.70 | 47.00 |
| Meadow/short grassland, no woody cover | 7.34 | 6.10 | 1.24 | 17.00 |
| Forb formations | 0.28 | 0.28 | 0.00 | 0.00 |
| **DESERT (bare soil)** | **15.85** | **15.58** | **0.27** | **2.00** |

**Source:** *Journal of Climate and Applied Meteorology.*
0 = zero or less than one-half the unit of measure.
For additional information, see Sources and Technical Notes.

# Table 4.3 MAJOR EARTHQUAKES, EVENTS AND DEATHS, 1900–85

| | 1900–09 | 1910–19 | 1920–29 | 1930–39 | 1940–49 | 1950–59 | 1960–69 | 1970–79 | 1980–85[a] | 1900–85 Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **WORLD TOTAL** | | | | | | | | | | |
| Earthquakes | **127** | **110** | **120** | **135** | **164** | **163** | **219** | **212** | **100** | **1,350** |
| Deaths | **115,516** | **64,009** | **603,344** | **171,526** | **69,372** | **12,380** | **54,804** | **425,694** | **20,012** | **1,536,657** |
| **WESTERN EUROPE AND SCANDINAVIA** | | | | | | | | | | |
| Earthquakes | 1 | 0 | 0 | 0 | 2 | 2 | 3 | 2 | 1 | 11 |
| Deaths | 40 | 0 | 0 | 0 | 0 | 7 | 8 | 0 | 2 | 57 |
| **SOUTHERN AND EASTERN EUROPE** | | | | | | | | | | |
| Earthquakes | 10 | 9 | 18 | 11 | 18 | 23 | 39 | 21 | 16 | 165 |
| Deaths | 68,874 | 32,166 | 1,887 | 1,613 | 1,070 | 945 | 1,611 | 2,682 | 3,150 | 113,998 |
| **AFRICA** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 4 | 3 | 3 | 4 | 12 | 3 | 2 | 31 |
| Deaths | 0 | 0 | 0 | 16 | 267 | 1,279 | 13,525 | 14 | 5,443 | 20,544 |
| **INDIAN OCEAN** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 4 | 1 | 0 | 1 | 3 | 0 | 1 | 10 |
| Deaths | 0 | 0 | 0 | 250 | 0 | 0 | 5 | 0 | 0 | 255 |
| **SOUTHWEST ASIA** | | | | | | | | | | |
| Earthquakes | 9 | 10 | 15 | 15 | 27 | 23 | 34 | 35 | 21 | 189 |
| Deaths | 28,106 | 371 | 7,639 | 44,127 | 20,425 | 5,582 | 27,768 | 56,082 | 9,689 | 199,789 |
| **USSR** | | | | | | | | | | |
| Earthquakes | 7 | 5 | 3 | 7 | 8 | 8 | 11 | 9 | 2 | 60 |
| Deaths | 6,262 | 490 | 3 | 148 | 20,209 | 1,251 | 125 | 1 | 0 | 28,489 |
| **EAST ASIA** | | | | | | | | | | |
| Earthquakes | 10 | 10 | 15 | 33 | 21 | 5 | 5 | 11 | 6 | 116 |
| Deaths | 1,156 | 12,895 | 488,647 | 88,171 | 1,090 | 133 | 3,001 | 240,279 | 216 | 835,588 |
| **JAPAN AND NORTHWEST PACIFIC ISLANDS** | | | | | | | | | | |
| Earthquakes | 22 | 15 | 14 | 18 | 12 | 16 | 22 | 17 | 7 | 143 |
| Deaths | 1,386 | 229 | 103,228 | 6,217 | 10,380 | 781 | 250 | 74 | 240 | 122,785 |
| **PHILIPPINES** | | | | | | | | | | |
| Earthquakes | 13 | 2 | 1 | 2 | 3 | 4 | 2 | 10 | 1 | 38 |
| Deaths | 14 | 50 | 600 | 0 | 72 | 454 | 234 | 8,034 | 24 | 9,482 |
| **INDONESIA AND SOUTHWEST PACIFIC ISLANDS** | | | | | | | | | | |
| Earthquakes | 17 | 25 | 9 | 16 | 17 | 16 | 24 | 35 | 14 | 173 |
| Deaths | 0 | 15,000 | 0 | 58 | 7 | 31 | 1,201 | 8,880 | 595 | 25,772 |
| **AUSTRALIA AND NEW ZEALAND** | | | | | | | | | | |
| Earthquakes | 1 | 0 | 1 | 4 | 1 | 0 | 1 | 1 | 0 | 9 |
| Deaths | 0 | 0 | 17 | 256 | 0 | 0 | 3 | 0 | 0 | 276 |
| **PACIFIC OCEAN** | | | | | | | | | | |
| Earthquakes | 1 | 2 | 1 | 0 | 2 | 2 | 0 | 3 | 1 | 12 |
| Deaths | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| **SOUTHERN AND WESTERN SOUTH AMERICA** | | | | | | | | | | |
| Earthquakes | 7 | 15 | 12 | 7 | 23 | 24 | 26 | 27 | 10 | 151 |
| Deaths | 5,260 | 190 | 609 | 28,062 | 15,491 | 548 | 6,503 | 80,861 | 474 | 137,998 |
| **BRAZIL** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| Deaths | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| **CARIBBEAN** | | | | | | | | | | |
| Earthquakes | 3 | 3 | 1 | 2 | 5 | 5 | 6 | 5 | 2 | 32 |
| Deaths | 1,400 | 116 | 0 | 34 | 130 | 13 | 239 | 9 | 15 | 1,956 |
| **PACIFIC NORTH AMERICA** | | | | | | | | | | |
| Earthquakes | 17 | 11 | 13 | 11 | 12 | 19 | 16 | 25 | 13 | 137 |
| Deaths | 3,018 | 2,501 | 662 | 2,570 | 49 | 1,323 | 215 | 28,774 | 102 | 39,214 |
| **ALASKA** | | | | | | | | | | |
| Earthquakes | 8 | 2 | 2 | 0 | 4 | 4 | 5 | 4 | 0 | 29 |
| Deaths | 0 | 0 | 0 | 0 | 178 | 5 | 115 | 0 | 0 | 298 |
| **ATLANTIC NORTH AMERICA** | | | | | | | | | | |
| Earthquakes | 1 | 1 | 4 | 5 | 2 | 5 | 3 | 1 | 2 | 24 |
| Deaths | 0 | 1 | 0 | 4 | 4 | 28 | 0 | 2 | 2 | 41 |
| **ATLANTIC OCEAN** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 2 | 0 | 3 | 1 | 6 | 3 | 1 | 16 |
| Deaths | 0 | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 60 | 112 |
| **ANTARCTICA** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Deaths | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ARCTIC** | | | | | | | | | | |
| Earthquakes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Deaths | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Source:** U.S. National Oceanic and Atmospheric Administration.
0 = zero; a = 1985 data are for January through mid-May only.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 4.1 Land Use, 1964–85

**Sources:** Land and land-use data: U.N. Food and Agriculture Organization, *FAO Production Yearbook 1983* and *1984* (U.N. Food and Agriculture Organization, Rome, 1984 and 1985), Table 1, and unpublished FAO data. Population data: U.N. Population Division, *World Population Prospects: Estimates and Projections as Assessed in 1982* (United Nations, New York, 1985).

Data for land area and land use are provided to the FAO by national governments in response to annual FAO questionnaires. Where official information is lacking, the FAO prepares its own estimates or relies on unofficial data.

Area data for land and inland water are for 1982. Inland water area refers to major rivers and lakes. Total area is the sum of inland water and land area and excludes national claims to the continental shelf and exclusive economic zones. The world total therefore excludes the oceans.

Arable land includes land under temporary crops, temporary meadows, land used for market and kitchen gardens, and temporarily fallow land. Permanent cropland is land under crops that do not need to be replanted after each harvest: cocoa, coffee, rubber, fruit trees, vines, etc. (It excludes land used to grow trees for wood or timber.)

Permanent pasture is land used five or more years for cultivated or wild forage crops.

Forests and woodland includes land under natural or planted stands of trees as well as logged-over areas that will be reforested in the near future.

Other land includes unused land, built-on areas, wasteland, parks, roads, etc.

Antarctica is included in the world area figures; however, the population density and land distribution figures for the world refer to the six inhabited continents.

Several countries use definitions of total area and land use that differ from those used above. Refer to the sources for details.

### Table 4.2 Land Use and Cover, Preagriculture to the Present

**Source:** Elaine Matthews, "Global Vegetation and Land Use: New High Resolution Data Bases for Climate Studies," *Journal of Climate and Applied Meteorology*, Vol. 22, pp. 474–487 (1983).

The author has developed two separate global geographic data bases: a vegetation data base of natural vegetation and a land-use data base of current land-use practices. The current extent of the world's natural and anthropogenic vegetation was calculated from the two data bases.

The vegetation data base provides information on preagricultural vegetation; the land-use data base (in conjunction with the vegetation data base) was used to calculate the amount of vegetation remaining. Both data bases were developed using cells of one degree latitude by one degree longitude. Cells in which there was less than 50 percent land were classified as water. Antarctica was excluded because vegetation is limited.

Vegetation was classified using the UNESCO classification system. This five-level scheme uses the following classification criteria: lifeform, density, seasonality (evergreen or deciduous), altitude, climate, and vegetation architecture. The UNESCO system is hierarchical, allowing a classification to have varying degrees of detail; for example, a vegetation type can be classified as a forest, an evergreen forest, a tropical evergreen forest, etc. This hierarchy allows aggregation and disaggregation to the limits of detail in the original data.

The UNESCO classification system identifies 225 vegetation types, of which the author used 178. These were aggregated into 30 broad categories for this table.

Approximately 40 sources, many of them national atlases, were used in compiling the land-use data base. The hierarchical land-use classification, which was developed by the author, took into account intensity and permanency of land-use activities. The land-use data base records the presence and type of agriculture in the one degree cells; 119 distinct land uses were identified. Different types of land use leave varying portions of the natural vegetation intact. For example, the author estimates that intensive subsistence rice cultivation and large-scale commercial cultivation leave 0 percent of the natural vegetation. Small scale commercial farms, dairies, plantations, and intensive subsistence agriculture leave 25 percent of the natural vegetation. Extensive subsistence agriculture with marginal cash crops leaves 50 percent of the natural vegetation. Rudimentary subsistence agriculture leaves 80 percent, while nomadic herding and grazing leaves 100 percent of the natural vegetation intact. Since urban areas are not the dominant land-use feature in any one cell, they are classified under cultivation.

As noted by the author, the major limitation of this analysis is that much of the data are from atlases prepared during the 1960s and 1970s. Although these data are adequate for the long-term climate analyses for which they were prepared, they do not reflect short-term changes in land use. There may have been significant changes in land use in certain ecosystems that were not taken into account in this study.

### Table 4.3 Major Earthquakes, Events and Deaths, 1900–85

**Source:** U.S. National Oceanic and Atmospheric Administration (NOAA), World Data Center for A Solid Earth Geophysics, *Catalog of Significant Earthquakes, 2000 BC-1979*, (U.S. National Oceanic and Atmospheric Administration, Boulder, Colorado, July, 1981). Data through May 11, 1985, were provided by NOAA.

Major earthquakes include earthquakes and any associated tsunamis that caused at least ten deaths, or caused at least $1 million in damage, or had an energy of at least 7.5 on the Richter scale. (The Richter scale measures earthquakes by the logarithm of their energy. An earthquake of magnitude 8.0 has ten times the energy of an earthquake of magnitude 7.0.)

The regions are defined as follows: *Western Europe and Scandinavia:* The Scandinavian peninsula, the British Isles, and Western Europe including the Federal Republic of Germany but excluding Italy; *Southern and Eastern Europe:* Italy, the German Democratic Republic, Eastern Europe, Greece, and the Mediterranean Sea; *Africa:* All of Africa, including Madagascar; *Southwest Asia:* India, Sri Lanka, Pakistan, Iran, Iraq, Turkey, Syria, Lebanon, Jordan, Israel, and the Arabian Peninsula; *Indian Ocean:* The open Indian Ocean, excluding Madagascar and Sri Lanka; *USSR:* All of the USSR; *East Asia:* Bangladesh, Burma, China, the Korean peninsula, and Southeast Asia; *Japan and Northwest Pacific Islands:* Sakhalin, Japan, Taiwan, the Kurile, Ryukyu, and Volcano Islands, the Sea of Okhotsk, the Sea of Japan, and the Yellow Sea; *Philippines:* The Philippine archipelago; *Indonesia and Southwest Pacific Islands:* The Indonesian archipelago and the Micronesian, Polynesian, and Melanesian islands; *Australia and New Zealand:* Australia, New Zealand, and the Tasman Sea and Indian Ocean to 60° S; *Pacific Ocean:* The open ocean from 60° S to 50° N, outside of archipelagic areas under Japan, the Philippines, and Indonesia as listed above; *Southern and Western South America:* Argentina, Chile, Peru, Bolivia, Paraguay, Ecuador, and the Pacific coast of Colombia; *Brazil:* Brazil and Uruguay; *Caribbean:* All Caribbean islands, the Caribbean coast of Colombia, Guyana, Suriname, and French Guiana; *Pacific North America:* Central America and the Pacific coast of the United States and Canada; *Alaska:* Alaska, including the Aleutian Islands; *Atlantic North America:* All of North America east of the Rocky Mountains; *Atlantic Ocean:* The Atlantic Ocean, excluding the Caribbean Sea and Gulf of Mexico, and including Iceland; *Antarctica:* All land and sea south of 60° S; and *Arctic:* All land and sea north of 70° N, including Greenland.

The NOAA data base of major earthquakes has been compiled from over 100 regional and global catalogs of earthquakes and from a constant stream of incoming reports. Since reporting has been more comprehensive in developed countries than in developing countries, especially in the early part of the century, the number of major earthquakes and their death tolls may have been underreported for many developing regions.

The most catastrophic earthquakes of this century were:

| Year | Country | Deaths |
|---|---|---|
| 1908 | Italy | 75,000 |
| 1915 | Italy | 30,000 |
| 1920 | China | 200,000 |
| 1923 | Japan | 99,000 |
| 1927 | China | 41,000 |
| 1932 | China | 70,000 |
| 1939 | Turkey | 30,000 |
| 1970 | Peru | 67,000 |
| 1976 | China | 240,000 |

# 5. Food and Agriculture

This section provides information on agricultural production; on the changing uses of agricultural inputs such as mechanical energy, water, and fertilizer; on trends in agricultural land holdings; and on soil erosion from cropland.

Indexes of agricultural production, shown in Table 5.1, summarize changes in output over the past two decades. Globally, agricultural output has increased approximately 20 percent since the mid-1970s: it increased in 119 countries and declined in 17 countries.

Trends in yields (metric tons of crop harvested per hectare per year) are shown for two of the most important groups of crops: cereals and roots and tubers. Roots and tubers (potatoes, cassava, yams, taro, sweet potatoes) are an important source of food and fiber in many tropical and subtropical countries. Over one third of Burundi's calorie supply, for example, is from roots and tubers. Their yield, however, has not increased over the 20-year period, but the population has grown almost 50 percent. Of the 49 African countries shown in Table 5.1, only 10 show a yield increase of greater than 30 percent since 1964–66.

The increased use of chemical fertilizers, tractors, and irrigation is responsible for much of the growth in yields. As Table 5.2 shows, the use of such inputs varies greatly by continent: Africa and South America use fewer inputs than do the Soviet Union, Asia, and North America. Europe is the largest user. For example, fertilizer use per hectare was less than 1 kilogram in the Central African Republic, 19 kilograms in Zambia, 115 kilograms in Costa Rica, and 754 kilograms in the Netherlands.

Table 5.3 shows three indicators of food production: an index of total production, an index of production per capita, and the number of food calories produced domestically as a percentage of calories consumed. Asia and Europe had the highest per capita gain since the mid-1970s, registering increases of over 10 percent. North and South America and Oceania had increases of 3 to 7 percent; the Soviet Union's per capita food production index was unchanged. Africa, although registering a 15 percent increase in gross food production, had a 10 percent decline in per capita food production.

One of the most important questions asked in recent years is whether a country is becoming more or less self-sufficient in food. If a country is becoming less self-sufficent, does it have the income to purchase food on the world market, or is it becoming more dependent on food aid? Of the 28 African countries that had a calorie surplus in the late 1960s, 18 had fallen into a deficit position by the late 1970s. Only 4 of the 28 (Ivory Coast, South Africa, Swaziland, and Zimbabwe) were able to increase their surpluses, usually by only a few percent. Canada, Argentina, Thailand, the United States, and Australia increased their food surpluses.

Land distribution data, summarized in Table 5.4, indicate the extent to which holdings are becoming more or less concentrated. For example, in France in 1960, 65 percent of the holdings (occupying 67 percent of the agricultural area) were 5–50 hectares in size; in 1980, 60 percent of the holdings (54 percent of the area) were 5–50 hectares. During the same period, holdings larger than 50 hectares increased from 6 to 12 percent of all holdings, and increased in area from 29 to 42 percent of the total. Note that the three size-classes in the table may hide important differences. In Bangladesh in 1977, for example, 54 percent of the agricultural holdings were under 1 hectare and only 9 percent were larger than 3 hectares.

One of the most serious problems in maintaining good cropland is the loss of topsoil. In Table 5.5 data from a number of studies of cropland erosion, carried out in the 1970s and 1980s, indicate the presence of severe soil erosion in many parts of the world. Although there is no single standard with which to judge the severity of erosion, rates in excess of 0.5 to 2.0 metric tons per hectare per year can affect crop productivity. However, the degree of impact varies greatly depending on the depth of topsoil in a particular area.

# Table 5.1 AGRICULTURAL PRODUCTION, 1964–84

| | Index of Agricultural Production (1974-76 = 100) | | | | Crop Yields (kilograms per hectare) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Per Agricultural Worker | | Cereals | | | Roots and Tubers | | |
| | 1964-66 | 1982-84 | 1964-66 | 1982-84 | 1964-66 | 1974-76 | 1982-84 | 1964-66 | 1974-76 | 1982-84 |
| **WORLD** | | **119** | | | | **1953** | **2373** | | **11579** | **12167** |
| **AFRICA** | | **114** | | | | **1005** | **942** | | **6874** | **7002** |
| Algeria | 70 | 102 | 73 | 104 | 513 | 682 | 599 | 7301 | 7340 | 6506 |
| Angola | 95 | 82 | 105 | 73 | 877 | 756 | 479 | 11589 | 13178 | 14045 |
| Benin | 81 | 121 | 87 | 112 | 538 | 721 | 678 | 6155 | 7654 | 7347 |
| Botswana | 80 | 86 | 95 | 80 | 317 | 599 | 229 | 4000 | 4641 | 5385 |
| Burkina Faso | 89 | 116 | 96 | 106 | 518 | 533 | 521 | 3352 | 4688 | 4444 |
| Burundi | 85 | 110 | 91 | 117 | 984 | 1134 | 1045 | 7778 | 6988 | 7115 |
| Cameroon | 66 | 103 | 75 | 94 | 1122 | 1017 | 917 | 3936 | 3516 | 2407 |
| Cape Verde | 150 | X | 177 | 100 | 691 | 448 | 454 | 6604 | 4244 | 3565 |
| Central African Rep | 76 | 108 | 84 | 98 | 753 | 518 | 549 | 3565 | 3231 | 3283 |
| Chad | 100 | 110 | 112 | 101 | 614 | 573 | 539 | 4562 | 4048 | 4456 |
| Comoros | 80 | X | 96 | 95 | 1308 | 1108 | 1118 | 3402 | 3451 | 3368 |
| Congo | 86 | 117 | 84 | 118 | 1125 | 665 | 566 | 4946 | 5668 | 6524 |
| Djibouti | X | X | X | X | X | X | X | X | X | X |
| Egypt | 82 | 111 | 93 | 102 | 3712 | 3921 | 4327 | 17311 | 17805 | 17307 |
| Equatorial Guinea | X | X | X | X | X | X | X | 3565 | 2736 | 2451 |
| Ethiopia | 92 | 122 | 107 | 112 | 775 | 966 | 1210 | 3046 | 3259 | 3144 |
| Gabon | 105 | 116 | 106 | 114 | 1570 | 1459 | 1520 | 6383 | 5866 | 6634 |
| Gambia | 84 | 89 | 95 | 86 | 1050 | 936 | 1003 | 4667 | 3274 | 3000 |
| Ghana | 74 | 87 | 78 | 79 | 892 | 873 | 636 | 8334 | 6136 | 6696 |
| Guinea | 78 | 109 | 86 | 100 | 811 | 832 | 878 | 7463 | 7115 | 7293 |
| Guinea-Bissau | 97 | 117 | 107 | 100 | 720 | 730 | 752 | 6154 | 4872 | 6154 |
| Ivory Coast | 66 | 136 | 88 | 113 | 800 | 813 | 904 | 3698 | 4145 | 3972 |
| Kenya | 68 | 123 | 91 | 100 | 1228 | 1564 | 1472 | 7363 | 7807 | 7900 |
| Lesotho | 86 | 91 | 98 | 90 | 780 | 772 | 844 | 14667 | 12951 | 15000 |
| Liberia | 67 | 112 | 77 | 99 | 698 | 1220 | 1158 | 4164 | 3886 | 3908 |
| Libya | 45 | 125 | 34 | 186 | 299 | 449 | 455 | 4535 | 5071 | 7644 |
| Madagascar | 75 | 110 | 88 | 100 | 1712 | 1805 | 1685 | 6361 | 6118 | 5899 |
| Malawi | 69 | 131 | 83 | 114 | 946 | 1057 | 1164 | 4858 | 3892 | 3997 |
| Mali | 85 | 131 | 98 | 116 | 784 | 779 | 742 | 8218 | 9041 | 9463 |
| Mauritania | 122 | 119 | 146 | 103 | 362 | 414 | 274 | 2511 | 1119 | 1871 |
| Mauritius | 91 | 104 | 95 | 94 | 1723 | 2589 | 2514 | 12318 | 15686 | 20009 |
| Morocco | 78 | 115 | 86 | 95 | 739 | 1049 | 910 | 10446 | 11449 | 13860 |
| Mozambique | 83 | 98 | 96 | 87 | 929 | 719 | 646 | 4822 | 4891 | 5852 |
| Niger | 108 | 141 | 128 | 123 | 522 | 395 | 372 | 8120 | 6620 | 6949 |
| Nigeria | 86 | 125 | 98 | 116 | 669 | 662 | 675 | 7910 | 10062 | 10005 |
| Rwanda | 59 | 145 | 76 | 120 | 1295 | 1037 | 1279 | 5674 | 8299 | 9137 |
| Senegal | 80 | 87 | 98 | 76 | 569 | 720 | 616 | 4250 | 3049 | 3485 |
| Sierra Leone | 84 | 108 | 84 | 109 | 1323 | 1428 | 1371 | 3624 | 4306 | 3330 |
| Somalia | 85 | 113 | 99 | 75 | 493 | 636 | 611 | 10000 | 10800 | 10841 |
| South Africa | 72 | 101 | 88 | 97 | 947 | 1403 | 1178 | 8292 | 12039 | 11663 |
| Sudan | 70 | 106 | 83 | 106 | 696 | 645 | 470 | 3457 | 3604 | 3500 |
| Swaziland | 56 | 146 | 61 | 134 | 471 | 1484 | 1294 | 3828 | 3777 | 2446 |
| Tanzania, United Rep | 79 | 116 | 99 | 98 | 789 | 980 | 964 | 5288 | 7027 | 10716 |
| Togo | 89 | 114 | 108 | 105 | 474 | 939 | 924 | 11919 | 13024 | 11231 |
| Tunisia | 68 | 105 | 65 | 105 | 691 | 824 | 827 | 8217 | 9500 | 13093 |
| Uganda | 53 | 117 | 67 | 92 | 901 | 1216 | 1620 | 4657 | 3729 | 3805 |
| Zaire | 79 | 121 | 90 | 107 | 688 | 745 | 821 | 6741 | 6882 | 6876 |
| Zambia | 60 | 96 | 70 | 86 | 846 | 1217 | 1637 | 3261 | 3378 | 3635 |
| Zimbabwe | 63 | 99 | 76 | 87 | 896 | 1446 | 936 | 4033 | 3985 | 4514 |
| **NORTH AMERICA** | | **115** | | | | **2895** | **3458** | | **18127** | **18795** |
| Barbados | 123 | 110 | 106 | 113 | 1910 | 2614 | 2500 | 8766 | 10659 | 13052 |
| Canada | 89 | 129 | 69 | 165 | 1743 | 2027 | 2245 | 18504 | 21501 | 23478 |
| Costa Rica | 60 | 113 | 71 | 100 | 1384 | 1735 | 1873 | 7350 | 8360 | 5690 |
| Cuba | 73 | 137 | 63 | 156 | 1178 | 2034 | 2779 | 5397 | 5435 | 6129 |
| Dominican Rep | 70 | 115 | 82 | 107 | 2081 | 2696 | 3112 | 6282 | 6073 | 6080 |
| El Salvador | 72 | 104 | 89 | 89 | 1179 | 1543 | 1709 | 7729 | 11724 | 13196 |
| Guatemala | 65 | 114 | 79 | 102 | 925 | 1459 | 1484 | 3821 | 3851 | 4526 |
| Haiti | 84 | 108 | 89 | 101 | 1068 | 1176 | 1034 | 4223 | 4320 | 4019 |
| Honduras | 76 | 143 | 93 | 115 | 1166 | 1093 | 1363 | 5356 | 3468 | 5287 |
| Jamaica | 88 | 98 | 69 | 112 | 1179 | 1763 | 1703 | 9234 | 10207 | 18127 |
| Mexico | 75 | 126 | 82 | 129 | 1309 | 1698 | 2208 | 8576 | 12070 | 13064 |
| Nicaragua | 68 | 94 | 75 | 87 | 1030 | 1045 | 1793 | 4133 | 4068 | 4039 |
| Panama | 73 | 120 | 81 | 117 | 960 | 1194 | 1481 | 8250 | 8230 | 7374 |
| Trinidad and Tobago | 82 | 67 | 87 | 78 | 2425 | 2859 | 3321 | 8913 | 11812 | 11775 |
| United States | 83 | 113 | 54 | 149 | 2901 | 3339 | 4098 | 21468 | 27227 | 29525 |
| **SOUTH AMERICA** | | **126** | | | | **1641** | **1959** | | **10968** | **10824** |
| Argentina | 78 | 121 | 73 | 129 | 1552 | 1971 | 2420 | 10002 | 13278 | 15561 |
| Bolivia | 62 | 100 | 71 | 92 | 953 | 1150 | 1212 | 5502 | 6975 | 5049 |
| Brazil | 70 | 135 | 77 | 130 | 1335 | 1420 | 1604 | 13054 | 12006 | 11174 |
| Chile | 89 | 117 | 83 | 119 | 1756 | 1679 | 2390 | 9287 | 9793 | 11206 |
| Colombia | 71 | 125 | 65 | 135 | 1338 | 2367 | 2533 | 7592 | 9243 | 11104 |
| Ecuador | 80 | 113 | 94 | 97 | 912 | 1352 | 1855 | 8224 | 10749 | 10109 |
| Guyana | 84 | 105 | 80 | 99 | 2031 | 2139 | 3191 | 6051 | 6604 | 6734 |
| Paraguay | 75 | 135 | 93 | 117 | 1263 | 1400 | 1269 | 13515 | 14144 | 14045 |
| Peru | 85 | 103 | 92 | 96 | 1551 | 1830 | 2674 | 6664 | 7007 | 7903 |
| Suriname | 64 | 140 | 49 | 168 | 3072 | 3630 | 3946 | 7058 | 5860 | 5000 |
| Uruguay | 90 | 112 | 70 | 125 | 969 | 1282 | 1917 | 4835 | 5250 | 5607 |
| Venezuela | 66 | 114 | 67 | 127 | 1260 | 1548 | 1982 | 8631 | 7647 | 8483 |

# Table 5.1

| | Index of Agricultural Production (1974-76 = 100) | | | | Crop Yields (kilograms per hectare) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Per Agricultural Worker | | Cereals | | | Roots and Tubers | | |
| | 1964-66 | 1982-84 | 1964-66 | 1982-84 | 1964-66 | 1974-76 | 1982-84 | 1964-66 | 1974-76 | 1982-84 |
| **ASIA** | | 130 | | | | 1822 | 2395 | | 12049 | 13938 |
| Afghanistan | 80 | 103 | 92 | 108 | 1065 | 1297 | 1333 | 10000 | 13727 | 13700 |
| Bahrain | X | X | X | X | X | X | X | 20000 | 29000 | 20953 |
| Bangladesh | 90 | 125 | 114 | 102 | 1645 | 1771 | 2033 | 8206 | 9945 | 10463 |
| Bhutan | 79 | 122 | 93 | 107 | 1419 | 1424 | 1413 | 6511 | 6602 | 6802 |
| Burma | 80 | 151 | 81 | 145 | 1525 | 1736 | 2932 | 3392 | 5628 | 8972 |
| China | 72 | 145 | 81 | 149 | 1750 | 2479 | 3698 | 9211 | 12904 | 15552 |
| Cyprus | 75 | 118 | 73 | 128 | 1059 | 1396 | 1626 | 15464 | 19842 | 21770 |
| India | 76 | 130 | 84 | 123 | 904 | 1179 | 1486 | 8841 | 12063 | 13775 |
| Indonesia | 70 | 141 | 76 | 137 | 1529 | 2338 | 3352 | 6976 | 8360 | 9315 |
| Iran | 63 | 123 | 72 | 118 | 873 | 1057 | 1107 | 17944 | 17273 | 14921 |
| Iraq | 78 | 117 | 90 | 114 | 779 | 854 | 736 | 10000 | 9019 | 19207 |
| Israel | 59 | 125 | 55 | 143 | 1650 | 2112 | 2205 | 23247 | 30599 | 45402 |
| Japan | 92 | 96 | 60 | 158 | 4409 | 5620 | 5521 | 18461 | 21297 | 23800 |
| Jordan | 171 | 172 | 166 | 191 | 1020 | 643 | 654 | 8826 | 11743 | 18564 |
| Kampuchea, Dem | 146 | 98 | 152 | 117 | 1118 | 1306 | 935 | 10132 | 8403 | 7720 |
| Korea, Dem People's Rep | 62 | 137 | 70 | 131 | 2864 | 3590 | 4105 | 10519 | 12191 | 12524 |
| Korea, Rep | 69 | 122 | 69 | 143 | 3031 | 4140 | 5356 | 16996 | 16953 | 19319 |
| Kuwait | X | X | X | X | X | 2000 | 3262 | X | 10500 | 15000 |
| Lao People's Dem Rep | 85 | 158 | 95 | 142 | 818 | 1312 | 1686 | 7492 | 9939 | 11547 |
| Lebanon | 90 | 132 | 54 | 248 | 951 | 1222 | 1211 | 11786 | 6979 | 14909 |
| Malaysia | 55 | 127 | 63 | 121 | 2087 | 2724 | 2647 | 9403 | 10506 | 10073 |
| Mongolia | 87 | 112 | 92 | 114 | 778 | 904 | 1147 | 7952 | 7655 | 10953 |
| Nepal | 83 | 110 | 102 | 96 | 1831 | 1755 | 1616 | 5717 | 5648 | 6128 |
| Oman | X | X | X | X | 3 | 1273 | 1754 | X | X | 3555 |
| Pakistan | 70 | 133 | 81 | 117 | 871 | 1389 | 1637 | 9225 | 10768 | 10302 |
| Philippines | 65 | 134 | 68 | 127 | 1048 | 1303 | 1723 | 5596 | 5293 | 6516 |
| Qatar | X | X | X | X | X | 3568 | 3711 | X | 10600 | 10000 |
| Saudi Arabia | 56 | 136 | 75 | 196 | 1324 | 737 | 1942 | 8775 | 5045 | 7500 |
| Singapore | 49 | 94 | 33 | 130 | X | X | X | 5762 | 6217 | 5865 |
| Sri Lanka | 82 | 127 | 97 | 111 | 1777 | 1825 | 2903 | 6196 | 4435 | 11080 |
| Syrian Arab Rep | 67 | 158 | 85 | 127 | 780 | 950 | 777 | X | 13047 | 15674 |
| Thailand | 67 | 136 | 80 | 125 | 1819 | 1882 | 1986 | 13042 | 14261 | 16394 |
| Turkey | 73 | 121 | 71 | 130 | 1176 | 1579 | 1925 | 11657 | 13870 | 16664 |
| United Arab Emirates | X | X | X | X | X | X | 2491 | X | 15533 | 14575 |
| Viet Nam | 87 | 148 | 94 | 137 | 1906 | 2127 | 2523 | 5820 | 6461 | 5307 |
| Yemen | 87 | 103 | 94 | 95 | 744 | 817 | 865 | 6184 | 10990 | 12368 |
| Yemen, Dem | 75 | 99 | 81 | 95 | 1228 | 1651 | 1549 | 5004 | 11364 | 10547 |
| **EUROPE** | | 115 | | | | 3178 | 3989 | | 18346 | 18770 |
| Albania | 74 | 128 | 87 | 115 | 1126 | 2112 | 2974 | 7842 | 7032 | 8029 |
| Austria | 84 | 115 | 51 | 163 | 2631 | 4000 | 4881 | 20469 | 23679 | 25636 |
| Belgium | 79 | 103 | 49 | 147 | 3613 | 4203 | 5542 | 30808 | 33463 | 35909 |
| Bulgaria | 82 | 115 | 67 | 155 | 2455 | 3460 | 4181 | 10840 | 11201 | 10613 |
| Czechoslovakia | 75 | 122 | 50 | 169 | 2202 | 3578 | 4403 | 15148 | 16026 | 18471 |
| Denmark | 100 | 127 | 67 | 171 | 3856 | 3705 | 4609 | 23382 | 22497 | 32935 |
| Finland | 87 | 103 | 54 | 153 | 1790 | 2592 | 3054 | 15002 | 14477 | 17054 |
| France | 87 | 115 | 57 | 156 | 2946 | 3776 | 5312 | 18671 | 20906 | 29555 |
| German Dem Rep | 80 | 106 | 59 | 131 | 2745 | 3575 | 4124 | 17829 | 15419 | 16438 |
| Germany, Fed Rep | 88 | 115 | 46 | 176 | 3044 | 3973 | 4880 | 24353 | 27133 | 28874 |
| Greece | 70 | 113 | 58 | 124 | 1705 | 2493 | 3300 | 9428 | 15003 | 16742 |
| Hungary | 73 | 126 | 49 | 189 | 2278 | 3806 | 5031 | 9106 | 12416 | 16497 |
| Ireland | 77 | 111 | 63 | 127 | 3104 | 3929 | 5466 | 22934 | 25666 | 27303 |
| Italy | 86 | 114 | 52 | 166 | 2347 | 3282 | 3667 | 10722 | 16551 | 17806 |
| Luxembourg | X | X | X | X | X | X | X | X | X | X |
| Malta | 69 | 141 | 58 | 127 | 1532 | 2089 | 3724 | 6318 | 8784 | 6985 |
| Netherlands | 69 | 125 | 55 | 166 | 3861 | 4771 | 6752 | 30147 | 35141 | 37460 |
| Norway | 92 | 120 | 59 | 160 | 2439 | 3052 | 3753 | 21437 | 22958 | 24091 |
| Poland | 79 | 101 | 74 | 105 | 1797 | 2673 | 2777 | 16411 | 18743 | 15880 |
| Portugal | 87 | 90 | 68 | 123 | 825 | 1118 | 1115 | 9360 | 8764 | 8416 |
| Romania | 67 | 126 | 62 | 145 | 1853 | 2628 | 3628 | 8610 | 12685 | 18418 |
| Spain | 68 | 115 | 45 | 152 | 1252 | 1834 | 2139 | 11533 | 14088 | 15933 |
| Sweden | 94 | 115 | 58 | 166 | 2979 | 3665 | 4036 | 23719 | 23499 | 27110 |
| Switzerland | 83 | 115 | 63 | 153 | 3382 | 4521 | 5481 | 25600 | 35544 | 36733 |
| United Kingdom | 91 | 124 | 64 | 157 | 3677 | 3930 | 5795 | 24080 | 25664 | 34346 |
| Yugoslavia | 77 | 118 | 66 | 144 | 2297 | 3292 | 4043 | 8263 | 8859 | 9321 |
| **USSR** | 77 | 106 | 51 | 141 | 1158 | 1466 | 1509 | 10586 | 11088 | 11986 |
| **OCEANIA** | | 115 | | | | 1420 | 1404 | | 9906 | 10382 |
| Australia | 83 | 114 | 74 | 136 | 1247 | 1384 | 1364 | 14973 | 19785 | 23891 |
| Fiji | 94 | 135 | 112 | 124 | 1738 | 2184 | 2061 | 8930 | 9463 | 9206 |
| New Zealand | 84 | 116 | 81 | 134 | 3376 | 3494 | 4751 | 20690 | 25365 | 25264 |
| Papua New Guinea | 76 | 123 | 90 | 106 | 2218 | 1871 | 1349 | 6793 | 6936 | 6973 |
| Solomon Islands | 86 | 166 | 98 | 142 | 2095 | 1995 | 3498 | 12796 | 13146 | 14992 |
| **ANTARCTICA** | | | | | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 5.2 AGRICULTURAL INPUTS, 1964–83

| | Arable and Permanent Cropland (thousand hectares) | | | Irrigated Land as Percentage of Arable and Permanent Cropland | | Fertilizer Use (kilograms of plant nutrient per hectare of arable and permanent cropland) | | | Tractors (number per thousand hectares of arable and permanent cropland) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1964–66 | 1974–76 | 1981–83 | 1974–76 | 1981–83 | 1964–66 | 1974–76 | 1981–83 | 1964–66 | 1974–76 | 1981–83 |
| **WORLD** | | 1435183 | 1469846 | 13 | 14 | | 60 | 78 | | 12.8 | 15.3 |
| **AFRICA** | | 176027 | 182821 | 4 | 4 | | 13 | 19 | | 2.2 | 2.7 |
| Algeria | 6774 | 7469 | 7510 | 4 | 5 | 7 | 20 | 19 | 4.3 | 5.5 | 8.6 |
| Angola | 3313 | 3500 | 3500 | 0 | 0 | 1 | 3 | 2 | 1.0 | 2.6 | 2.9 |
| Benin | 1439 | 1762 | 1802 | 1 | 1 | 1 | 2 | 2 | 0.1 | 0.0 | 0.1 |
| Botswana | 1027 | 1330 | 1360 | 0 | 0 | 2 | 2 | 1 | 1.1 | 1.4 | 1.6 |
| Burkina Faso | 2179 | 2509 | 2633 | 0 | 0 | 0 | 0 | 4 | 0.0 | 0.0 | 0.0 |
| Burundi | 988 | 1255 | 1306 | 0 | 0 | 0 | 1 | 1 | 0.0 | 0.0 | 0.0 |
| Cameroon | 5740 | 6395 | 6950 | 0 | 0 | 2 | 2 | 6 | 0.0 | 0.0 | 0.1 |
| Cape Verde | 40 | 40 | 40 | 5 | 5 | X | 0 | 0 | 0.2 | 0.7 | 0.8 |
| Central African Rep | 1780 | 1887 | 1958 | 0 | 0 | 0 | 1 | 0 | 0.0 | 0.1 | 0.1 |
| Chad | 2900 | 3007 | 3152 | 0 | 0 | 0 | 2 | 2 | 0.0 | 0.0 | 0.1 |
| Comoros | 85 | 90 | 92 | 0 | 0 | X | 0 | 0 | X | 0.0 | 0.0 |
| Congo | 624 | 652 | 672 | 0 | 0 | 3 | 5 | 2 | 0.6 | 1.0 | 1.0 |
| Djibouti | X | 0 | 0 | 0 | 0 | X | 0 | 0 | X | 0.0 | 0.0 |
| Egypt | 2653 | 2799 | 2469 | 100 | 100 | 117 | 166 | 311 | 5.5 | 8.7 | 16.2 |
| Equatorial Guinea | 222 | 230 | 230 | 0 | 0 | 3 | 0 | 0 | 0.2 | 0.4 | 0.4 |
| Ethiopia | 12442 | 13730 | 13953 | 0 | 0 | 0 | 2 | 3 | 0.1 | 0.3 | 0.3 |
| Gabon | 205 | 374 | 452 | 0 | 0 | X | 0 | 2 | 1.6 | 2.2 | 2.9 |
| Gambia | 125 | 151 | 159 | 17 | 21 | 3 | 7 | 12 | 0.4 | 0.3 | 0.3 |
| Ghana | 2627 | 2700 | 2767 | 1 | 1 | 0 | 6 | 10 | 0.8 | 1.2 | 1.3 |
| Guinea | 1570 | 1570 | 1574 | 0 | 1 | 2 | 1 | 2 | 0.0 | 0.1 | 0.1 |
| Guinea-Bissau | 263 | 285 | 287 | 0 | 0 | X | 0 | 4 | 0.1 | 0.1 | 0.2 |
| Ivory Coast | 2670 | 3483 | 3962 | 1 | 1 | 4 | 10 | 10 | 0.3 | 0.5 | 0.8 |
| Kenya | 1890 | 2240 | 2336 | 2 | 2 | 13 | 22 | 32 | 3.1 | 2.6 | 2.8 |
| Lesotho | 357 | 361 | 298 | 0 | 0 | 2 | 4 | 15 | 0.6 | 3.6 | 5.0 |
| Liberia | 372 | 366 | 371 | 1 | 1 | 2 | 11 | 9 | 0.3 | 0.7 | 0.8 |
| Libya | 1997 | 2054 | 2091 | 10 | 11 | 3 | 14 | 38 | 1.6 | 6.3 | 12.4 |
| Madagascar | 2245 | 2666 | 3004 | 16 | 16 | 2 | 3 | 4 | 0.8 | 0.8 | 0.9 |
| Malawi | 1987 | 2273 | 2332 | 0 | 0 | 2 | 6 | 14 | 0.2 | 0.4 | 0.5 |
| Mali | 1688 | 1900 | 2055 | 5 | 5 | 1 | 2 | 5 | 0.2 | 0.4 | 0.4 |
| Mauritania | 273 | 188 | 199 | 4 | 4 | 0 | 3 | 0 | 0.1 | 1.0 | 1.6 |
| Mauritius | 93 | 106 | 107 | 14 | 15 | 245 | 241 | 224 | 3.0 | 2.8 | 3.1 |
| Morocco | 7223 | 7699 | 8401 | 6 | 6 | 7 | 21 | 26 | 1.1 | 2.4 | 2.9 |
| Mozambique | 2687 | 3080 | 3080 | 2 | 2 | 2 | 2 | 13 | 1.0 | 1.8 | 1.9 |
| Niger | 2260 | 2497 | 3590 | 1 | 1 | 0 | 0 | 1 | 0.0 | 0.0 | 0.0 |
| Nigeria | 29197 | 30000 | 30418 | 0 | 0 | 0 | 1 | 7 | 0.0 | 0.2 | 0.3 |
| Rwanda | 655 | 912 | 1018 | 0 | 0 | X | 0 | 1 | 0.1 | 0.1 | 0.1 |
| Senegal | 4500 | 5000 | 5226 | 3 | 3 | 3 | 9 | 4 | 0.1 | 0.1 | 0.1 |
| Sierra Leone | 1435 | 1603 | 1769 | 0 | 0 | 0 | 1 | 1 | 0.1 | 0.1 | 0.2 |
| Somalia | 981 | 1055 | 1083 | 16 | 15 | 1 | 3 | 1 | 0.8 | 1.2 | 1.5 |
| South Africa | 13055 | 13393 | 13620 | 8 | 8 | 29 | 56 | 87 | 10.6 | 12.9 | 13.3 |
| Sudan | 11200 | 12160 | 12448 | 13 | 14 | 2 | 6 | 6 | 0.2 | 0.7 | 0.9 |
| Swaziland | 143 | 164 | 139 | 16 | 22 | 35 | 55 | 129 | 5.4 | 14.9 | 20.7 |
| Tanzania, United Rep | 3797 | 5030 | 5193 | 1 | 1 | 2 | 6 | 5 | 4.6 | 3.5 | 3.6 |
| Togo | 1123 | 1415 | 1426 | 0 | 1 | 0 | 1 | 2 | 0.0 | 0.1 | 0.2 |
| Tunisia | 4334 | 4860 | 4786 | 3 | 4 | 5 | 10 | 17 | 3.3 | 5.0 | 5.5 |
| Uganda | 4876 | 5403 | 5967 | 0 | 0 | 1 | 1 | 0 | 0.1 | 0.3 | 0.5 |
| Zaire | 5670 | 6117 | 6406 | 0 | 0 | 0 | 1 | 1 | 0.2 | 0.2 | 0.3 |
| Zambia | 4860 | 4998 | 5158 | 0 | 0 | 2 | 12 | 19 | 0.3 | 0.8 | 0.9 |
| Zimbabwe | 2118 | 2524 | 2714 | 3 | 4 | 35 | 60 | 60 | 6.9 | 7.0 | 7.5 |
| **NORTH AMERICA** | | 267067 | 273206 | 9 | 10 | | 77 | 83 | | 21.7 | 20.2 |
| Barbados | 33 | 33 | 33 | 0 | 0 | 211 | 167 | 182 | 10.5 | 14.5 | 17.2 |
| Canada | 41550 | 43363 | 46194 | 1 | 1 | 17 | 29 | 43 | 14.1 | 13.5 | 14.2 |
| Costa Rica | 485 | 508 | 629 | 5 | 4 | 59 | 137 | 115 | 9.5 | 8.9 | 9.6 |
| Cuba | 1846 | 3087 | 3213 | 19 | 31 | 134 | 103 | 181 | 11.9 | 16.2 | 20.6 |
| Dominican Rep | 1050 | 1263 | 1445 | 11 | 12 | 12 | 68 | 38 | 2.1 | 1.9 | 2.2 |
| El Salvador | 658 | 657 | 725 | 5 | 15 | 71 | 147 | 102 | 2.7 | 4.0 | 4.6 |
| Guatemala | 1544 | 1648 | 1785 | 4 | 4 | 14 | 36 | 50 | 1.7 | 2.1 | 2.3 |
| Haiti | 730 | 860 | 897 | 8 | 8 | 0 | 2 | 6 | 0.4 | 0.5 | 0.6 |
| Honduras | 1507 | 1634 | 1768 | 5 | 5 | 6 | 12 | 15 | 0.3 | 1.6 | 1.9 |
| Jamaica | 287 | 262 | 267 | 12 | 12 | 62 | 84 | 64 | 13.7 | 9.3 | 10.9 |
| Mexico | 23482 | 23200 | 23500 | 20 | 22 | 15 | 42 | 72 | 3.1 | 4.2 | 6.7 |
| Nicaragua | 1192 | 1230 | 1260 | 5 | 6 | 17 | 22 | 33 | 0.2 | 0.8 | 1.8 |
| Panama | 558 | 559 | 582 | 4 | 5 | 17 | 47 | 49 | 2.2 | 6.3 | 7.0 |
| Trinidad and Tobago | 139 | 157 | 158 | 12 | 13 | 56 | 51 | 35 | 11.8 | 13.3 | 15.6 |
| United States | 178754 | 188218 | 190388 | 9 | 11 | 63 | 93 | 94 | 28.1 | 26.9 | 24.2 |
| **SOUTH AMERICA** | | 121659 | 138121 | 5 | 6 | | 22 | 27 | | 4.2 | 4.9 |
| Argentina | 29286 | 34650 | 35567 | 4 | 5 | 1 | 2 | 3 | 5.3 | 5.1 | 4.3 |
| Bolivia | 1640 | 3264 | 3375 | 4 | 4 | 1 | 1 | 1 | 0.2 | 0.2 | 0.2 |
| Brazil | 51390 | 60672 | 74213 | 2 | 3 | 5 | 31 | 37 | 2.3 | 3.4 | 4.6 |
| Chile | 4427 | 5260 | 5528 | 24 | 23 | 26 | 25 | 20 | 7.6 | 6.2 | 6.3 |
| Colombia | 5053 | 5318 | 5673 | 5 | 6 | 28 | 44 | 53 | 4.1 | 4.3 | 5.0 |
| Ecuador | 2527 | 2583 | 2550 | 20 | 21 | 6 | 14 | 28 | 0.8 | 2.0 | 2.0 |
| Guyana | 362 | 388 | 495 | 31 | 25 | 23 | 37 | 25 | 9.1 | 6.8 | 7.1 |
| Paraguay | 903 | 1233 | 1940 | 4 | 3 | 2 | 1 | 4 | 1.9 | 1.6 | 4.1 |
| Peru | 2648 | 3222 | 3516 | 35 | 34 | 29 | 38 | 32 | 3.2 | 3.5 | 4.7 |
| Suriname | 38 | 45 | 57 | 67 | 68 | 33 | 89 | 120 | 20.0 | 21.6 | 40.9 |
| Uruguay | 1406 | 1439 | 1448 | 4 | 6 | 29 | 40 | 41 | 17.6 | 20.6 | 23.2 |
| Venezuela | 3484 | 3582 | 3756 | 8 | 8 | 10 | 38 | 40 | 4.4 | 7.4 | 10.7 |

# Table 5.2

| | Arable and Permanent Cropland (thousand hectares) | | | Irrigated Land as Percentage of Arable and Permanent Cropland | | Fertilizer Use (kilograms of plant nutrient per hectare of arable and permanent cropland) | | | Tractors (number per thousand hectares of arable and permanent cropland) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1964–66 | 1974–76 | 1981–83 | 1974–76 | 1981–83 | 1964–66 | 1974–76 | 1981–83 | 1964–66 | 1974–76 | 1981–83 |
| **ASIA** | | **452035** | **455838** | **27** | **29** | | **35** | **71** | | **4.2** | **8.5** |
| Afghanistan | 7887 | 8048 | 8054 | 31 | 33 | 0 | 4 | 6 | 0.0 | 0.1 | 0.1 |
| Bahrain | 2 | 2 | 2 | 50 | 50 | X | 0 | 104 | X | 0.0 | 0.0 |
| Bangladesh | 9002 | 9129 | 9134 | 15 | 20 | 6 | 19 | 48 | 0.1 | 0.3 | 0.5 |
| Bhutan | 69 | 84 | 96 | 0 | 0 | X | 0 | 1 | X | 0.0 | 0.0 |
| Burma | 10295 | 9985 | 10071 | 10 | 10 | 1 | 5 | 15 | 0.3 | 0.8 | 0.9 |
| China | 103533 | 101075 | 100895 | 42 | 45 | 24 | 61 | 155 | 0.8 | 4.4 | 8.1 |
| Cyprus | 432 | 432 | 432 | 22 | 22 | 38 | 46 | 41 | 11.5 | 22.6 | 25.5 |
| India | 162424 | 167810 | 168760 | 20 | 23 | 5 | 15 | 34 | 0.3 | 1.3 | 2.7 |
| Indonesia | 17380 | 19516 | 19820 | 25 | 27 | 6 | 25 | 75 | 0.4 | 0.5 | 0.7 |
| Iran | 15453 | 16450 | 13700 | 36 | 30 | 3 | 20 | 57 | 0.9 | 3.2 | 5.5 |
| Iraq | 4903 | 5287 | 5450 | 30 | 32 | 1 | 6 | 14 | 1.3 | 3.6 | 5.3 |
| Israel | 407 | 420 | 425 | 43 | 49 | 96 | 167 | 179 | 26.3 | 47.0 | 63.4 |
| Japan | 5868 | 5092 | 4829 | 64 | 67 | 333 | 378 | 400 | 9.9 | 145.2 | 312.2 |
| Jordan | 349 | 391 | 413 | 9 | 9 | 12 | 14 | 26 | 5.4 | 9.1 | 11.9 |
| Kampuchea, Dem | 2900 | 3046 | 3046 | 3 | 3 | 1 | 0 | 5 | 0.3 | 0.4 | 0.4 |
| Korea, Dem People's Rep | 1931 | 2140 | 2272 | 42 | 47 | 90 | 199 | 336 | 6.8 | 11.0 | 24.6 |
| Korea, Rep | 2240 | 2239 | 2178 | 47 | 54 | 167 | 383 | 317 | 0.0 | 0.3 | 2.6 |
| Kuwait | 1 | 1 | 2 | 100 | 60 | X | 0 | 370 | 3.0 | 10.2 | 15.2 |
| Lao People's Dem Rep | 833 | 848 | 888 | 5 | 13 | 1 | 0 | 2 | 0.1 | 0.4 | 0.8 |
| Lebanon | 291 | 335 | 298 | 26 | 29 | 69 | 82 | 134 | 6.5 | 10.1 | 10.1 |
| Malaysia | 3700 | 4199 | 4337 | 7 | 8 | 27 | 56 | 97 | 0.7 | 1.3 | 1.8 |
| Mongolia | 834 | 859 | 1259 | 3 | 3 | X | 5 | 11 | 5.0 | 6.3 | 8.3 |
| Nepal | 1831 | 2326 | 2331 | 8 | 10 | 1 | 5 | 12 | 0.2 | 0.2 | 0.2 |
| Oman | 26 | 37 | 42 | 92 | 94 | X | 0 | 33 | 0.3 | 1.6 | 2.6 |
| Pakistan | 19234 | 19715 | 20372 | 69 | 72 | 5 | 25 | 57 | 0.4 | 1.9 | 6.0 |
| Philippines | 9210 | 9832 | 11387 | 11 | 12 | 11 | 26 | 29 | 0.6 | 1.1 | 1.6 |
| Qatar | 1 | 2 | 3 | 0 | 0 | X | 0 | 277 | 13.0 | 12.7 | 24.8 |
| Saudi Arabia | 767 | 1108 | 1131 | 34 | 35 | 8 | 8 | 72 | 0.3 | 0.7 | 1.2 |
| Singapore | 13 | 8 | 6 | 0 | 0 | 185 | 375 | 742 | 0.6 | 5.2 | 7.6 |
| Sri Lanka | 1875 | 2066 | 2172 | 23 | 25 | 51 | 42 | 70 | 4.1 | 7.2 | 11.8 |
| Syrian Arab Rep | 6461 | 5725 | 5722 | 10 | 10 | 3 | 9 | 25 | 1.2 | 2.7 | 6.1 |
| Thailand | 12607 | 16677 | 19009 | 14 | 18 | 3 | 11 | 19 | 0.3 | 1.3 | 5.4 |
| Turkey | 26207 | 27764 | 27395 | 7 | 8 | 6 | 25 | 50 | 2.1 | 8.8 | 17.8 |
| United Arab Emirates | 9 | 12 | 14 | 42 | 36 | X | 83 | 283 | X | 0.0 | 0.0 |
| Viet Nam | 5985 | 6273 | 6779 | 17 | 25 | 12 | 49 | 38 | 0.5 | 1.1 | 5.6 |
| Yemen | 2697 | 2785 | 2790 | 8 | 9 | 0 | 1 | 5 | 0.1 | 0.4 | 0.8 |
| Yemen, Dem | 174 | 195 | 209 | 29 | 31 | X | 3 | 10 | 3.7 | 4.5 | 5.1 |
| **EUROPE** | | **142138** | **140532** | **9** | **11** | | **196** | **223** | | **51.2** | **63.1** |
| Albania | 521 | 668 | 708 | 49 | 54 | 15 | 95 | 135 | 8.5 | 13.2 | 15.3 |
| Austria | 1713 | 1613 | 1600 | 0 | 0 | 180 | 202 | 234 | 112.1 | 181.0 | 201.8 |
| Belgium | 1000 | 894 | 831 | 0 | 0 | 466 | 544 | 505 | 68.6 | 127.1 | 137.6 |
| Bulgaria | 4567 | 4386 | 4152 | 26 | 29 | 82 | 142 | 251 | 9.2 | 15.4 | 14.3 |
| Czechoslovakia | 5262 | 5268 | 5170 | 3 | 3 | 167 | 307 | 335 | 23.4 | 27.4 | 25.8 |
| Denmark | 2716 | 2661 | 2647 | 7 | 15 | 183 | 228 | 240 | 59.4 | 70.1 | 68.9 |
| Finland | 2526 | 2481 | 2364 | 2 | 3 | 135 | 223 | 209 | 50.1 | 78.2 | 95.6 |
| France | 20528 | 18859 | 18655 | 4 | 6 | 155 | 248 | 299 | 48.7 | 72.8 | 82.0 |
| German Dem Rep | 5009 | 4942 | 5006 | 3 | 3 | 257 | 371 | 313 | 24.9 | 27.9 | 30.0 |
| Germany, Fed Rep | 7639 | 7576 | 7465 | 4 | 4 | 367 | 419 | 427 | 152.1 | 191.6 | 196.7 |
| Greece | 3851 | 3873 | 3953 | 23 | 25 | 66 | 115 | 148 | 10.2 | 23.6 | 40.1 |
| Hungary | 5634 | 5490 | 5303 | 5 | 3 | 64 | 260 | 284 | 11.2 | 11.7 | 10.4 |
| Ireland | 1252 | 1006 | 972 | 0 | 0 | 197 | 394 | 622 | 47.7 | 116.7 | 149.9 |
| Italy | 15311 | 12318 | 12354 | 22 | 24 | 68 | 112 | 164 | 27.4 | 66.5 | 92.1 |
| Luxembourg | X | X | X | X | X | X | X | X | X | X | X |
| Malta | 14 | 13 | 14 | 8 | 7 | 30 | 0 | 25 | 6.6 | 23.6 | 31.4 |
| Netherlands | 964 | 841 | 862 | 51 | 49 | 582 | 757 | 754 | 97.5 | 181.8 | 214.6 |
| Norway | 849 | 793 | 841 | 5 | 9 | 196 | 291 | 309 | 84.8 | 125.7 | 166.4 |
| Poland | 15769 | 15067 | 14826 | 1 | 1 | 84 | 237 | 220 | 7.9 | 27.0 | 48.0 |
| Portugal | 4170 | 3620 | 3550 | 17 | 18 | 40 | 63 | 75 | 3.8 | 12.8 | 21.4 |
| Romania | 10491 | 10496 | 10531 | 15 | 23 | 25 | 101 | 144 | 7.9 | 11.5 | 15.6 |
| Spain | X | 20792 | 20496 | 14 | 15 | X | 70 | 70 | X | 18.5 | 27.8 |
| Sweden | 3179 | 3009 | 2979 | 2 | 2 | 121 | 168 | 162 | 53.9 | 62.8 | 63.7 |
| Switzerland | 403 | 393 | 411 | 6 | 6 | 324 | 366 | 413 | 159.4 | 200.1 | 248.6 |
| United Kingdom | 5449 | 7028 | 6987 | 1 | 2 | 288 | 249 | 347 | 87.0 | 69.3 | 74.7 |
| Yugoslavia | 8305 | 8035 | 7839 | 2 | 2 | 57 | 87 | 124 | 6.1 | 28.8 | 62.7 |
| **USSR** | **229350** | **232406** | **232276** | **6** | **8** | **X** | **69** | **85** | **X** | **10.0** | **11.4** |
| **OCEANIA** | | **43850** | **47051** | **4** | **4** | | **30** | **35** | | **9.1** | **9.2** |
| Australia | 37503 | 42315 | 45433 | 3 | 4 | 28 | 19 | 25 | 8.1 | 7.3 | 7.3 |
| Fiji | 206 | 230 | 236 | 0 | 0 | 32 | 52 | 69 | 5.5 | 6.0 | 6.8 |
| New Zealand | 487 | 411 | 464 | 36 | 43 | 908 | 1187 | 1014 | 186.2 | 201.7 | 207.2 |
| Papua New Guinea | 310 | 351 | 371 | 0 | 0 | 1 | 19 | 24 | 3.8 | 3.2 | 4.0 |
| Solomon Islands | 50 | 50 | 53 | 0 | 0 | X | 0 | 0 | X | 0.0 | 0.0 |
| **ANTARCTICA** | | | | | | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 5.3 FOOD PRODUCTION AND CONSUMPTION, 1964–84

| | Index of Food Production (1974–76 = 100) | | | | Calories Domestically Produced as Percentage of Total Supply | |
|---|---|---|---|---|---|---|
| | Total | | Per Capita | | | |
| | 1964–66 | 1982–84 | 1964–66 | 1982–84 | 1967–70 | 1977–80 |
| **WORLD** | | **119** | | **104** | **101** | **101** |
| **AFRICA** | | **115** | | **90** | **102** | **93** |
| Algeria | 70 | 101 | 95 | 79 | 85 | 58 |
| Angola | 86 | 103 | 109 | 81 | 109 | 86 |
| Benin | 82 | 120 | 100 | 97 | 110 | 100 |
| Botswana | 80 | 86 | 116 | 64 | 68 | 52 |
| Burkina Faso | 90 | 114 | 108 | 96 | 102 | 95 |
| Burundi | 86 | 108 | 101 | 92 | 99 | 98 |
| Cameroon | 65 | 101 | 82 | 83 | 104 | 98 |
| Cape Verde | 149 | X | 188 | X | 58 | 46 |
| Central African Rep | 76 | 111 | 91 | 94 | 98 | 99 |
| Chad | 103 | 114 | 124 | 96 | 98 | 100 |
| Comoros | 81 | X | 108 | X | 93 | 86 |
| Congo | 86 | 117 | 108 | 96 | 113 | 89 |
| Djibouti | X | X | X | X | X | X |
| Egypt | 77 | 112 | 96 | 91 | 91 | 79 |
| Equatorial Guinea | X | X | X | X | X | X |
| Ethiopia | 92 | 121 | 118 | 102 | 101 | 97 |
| Gabon | 104 | 116 | 116 | 103 | 90 | 72 |
| Gambia | 84 | 89 | 105 | 76 | 127 | 112 |
| Ghana | 75 | 87 | 97 | 68 | 106 | 98 |
| Guinea | 78 | 109 | 96 | 91 | 100 | 93 |
| Guinea-Bissau | 100 | 117 | 119 | 86 | 105 | 88 |
| Ivory Coast | 60 | 148 | 90 | 109 | 104 | 106 |
| Kenya | 70 | 117 | 101 | 85 | 102 | 97 |
| Lesotho | 81 | 89 | 96 | 73 | 84 | 73 |
| Liberia | 67 | 116 | 89 | 90 | 93 | 87 |
| Libya | 45 | 126 | 74 | 92 | 54 | 45 |
| Madagascar | 74 | 112 | 93 | 90 | 103 | 98 |
| Malawi | 72 | 127 | 93 | 100 | 105 | 104 |
| Mali | 87 | 129 | 108 | 107 | 99 | 96 |
| Mauritania | 122 | 119 | 158 | 95 | 81 | 54 |
| Mauritius | 91 | 103 | 103 | 89 | 178 | 158 |
| Morocco | 78 | 116 | 106 | 91 | 98 | 79 |
| Mozambique | 80 | 100 | 108 | 73 | 110 | 97 |
| Niger | 108 | 141 | 138 | 115 | 111 | 104 |
| Nigeria | 86 | 126 | 117 | 96 | 105 | 93 |
| Rwanda | 59 | 145 | 81 | 111 | 99 | 98 |
| Senegal | 81 | 86 | 115 | 67 | 112 | 95 |
| Sierra Leone | 84 | 108 | 97 | 95 | 101 | 96 |
| Somalia | 85 | 113 | 108 | 68 | 94 | 80 |
| South Africa | 69 | 101 | 87 | 83 | 115 | 116 |
| Sudan | 71 | 108 | 93 | 85 | 103 | 100 |
| Swaziland | 58 | 144 | 75 | 114 | 147 | 151 |
| Tanzania, United Rep | 71 | 126 | 99 | 96 | 101 | 98 |
| Togo | 88 | 113 | 121 | 92 | 104 | 95 |
| Tunisia | 69 | 104 | 84 | 85 | 81 | 76 |
| Uganda | 80 | 119 | 84 | 91 | 102 | 98 |
| Zaire | 80 | 121 | 101 | 96 | 102 | 96 |
| Zambia | 58 | 94 | 79 | 73 | 92 | 89 |
| Zimbabwe | 55 | 90 | 76 | 69 | 113 | 114 |
| **NORTH AMERICA** | | **117** | | **104** | **116** | **130** |
| Barbados | 123 | 110 | 135 | 103 | 158 | 118 |
| Canada | 89 | 129 | 105 | 118 | 131 | 143 |
| Costa Rica | 57 | 104 | 76 | 83 | 109 | 109 |
| Cuba | 73 | 138 | 90 | 130 | 148 | 139 |
| Dominican Rep | 69 | 117 | 94 | 97 | 135 | 121 |
| El Salvador | 69 | 112 | 92 | 89 | 97 | 97 |
| Guatemala | 63 | 126 | 87 | 100 | 101 | 104 |
| Haiti | 82 | 109 | 99 | 90 | 98 | 87 |
| Honduras | 74 | 138 | 101 | 104 | 113 | 104 |
| Jamaica | 88 | 98 | 108 | 88 | 115 | 81 |
| Mexico | 70 | 130 | 102 | 104 | 105 | 94 |
| Nicaragua | 64 | 99 | 88 | 78 | 110 | 107 |
| Panama | 72 | 118 | 93 | 99 | 106 | 109 |
| Trinidad and Tobago | 81 | 67 | 104 | 66 | 104 | 76 |
| United States | 82 | 114 | 87 | 105 | 115 | 134 |
| **SOUTH AMERICA** | | **128** | | **107** | **107** | **108** |
| Argentina | 77 | 123 | 91 | 108 | 139 | 153 |
| Bolivia | 64 | 103 | 81 | 83 | 88 | 93 |
| Brazil | 64 | 139 | 81 | 116 | 102 | 105 |
| Chile | 88 | 116 | 108 | 101 | 88 | 82 |
| Colombia | 68 | 123 | 90 | 104 | 99 | 96 |
| Ecuador | 81 | 114 | 107 | 89 | 108 | 99 |
| Guyana | 83 | 104 | 102 | 89 | 148 | 135 |
| Paraguay | 79 | 136 | 101 | 105 | 99 | 112 |
| Peru | 80 | 103 | 106 | 83 | 96 | 87 |
| Suriname | 64 | 140 | 75 | 146 | 100 | 105 |
| Uruguay | 85 | 110 | 89 | 105 | 101 | 103 |
| Venezuela | 65 | 116 | 99 | 88 | 84 | 70 |

# Table 5.3

| | Index of Food Production (1974–76 = 100) Total 1964–66 | Index of Food Production (1974–76 = 100) Total 1982–84 | Index of Food Production (1974–76 = 100) Per Capita 1964–66 | Index of Food Production (1974–76 = 100) Per Capita 1982–84 | Calories Domestically Produced as Percentage of Total Supply 1967–70 | Calories Domestically Produced as Percentage of Total Supply 1977–80 |
|---|---|---|---|---|---|---|
| **ASIA** | | **130** | | **112** | **98** | **96** |
| Afghanistan | 82 | 108 | 99 | 106 | 98 | 98 |
| Bahrain | X | X | X | X | X | X |
| Bangladesh | 88 | 125 | 115 | 100 | 96 | 95 |
| Bhutan | 79 | 122 | 96 | 104 | 84 | 84 |
| Burma | 80 | 152 | 104 | 124 | 105 | 105 |
| China | 72 | 141 | 93 | 126 | 100 | 98 |
| Cyprus | 74 | 118 | 83 | 111 | 86 | 59 |
| India | 75 | 131 | 94 | 110 | 100 | 100 |
| Indonesia | 69 | 142 | 87 | 121 | 100 | 99 |
| Iran | 62 | 125 | 87 | 98 | 96 | 81 |
| Iraq | 78 | 118 | 107 | 89 | 92 | 66 |
| Israel | 61 | 119 | 79 | 100 | 54 | 49 |
| Japan | 91 | 97 | 106 | 91 | 73 | 61 |
| Jordan | 172 | 172 | 228 | 137 | 63 | 38 |
| Kampuchea, Dem | 141 | 99 | 162 | 98 | 112 | 93 |
| Korea, Dem People's Rep | 61 | 137 | 79 | 113 | 96 | 98 |
| Korea, Rep | 70 | 125 | 88 | 111 | 89 | 78 |
| Kuwait | X | X | X | X | X | X |
| Lao People's Dem Rep | 84 | 158 | 108 | 129 | 96 | 93 |
| Lebanon | 90 | 137 | 117 | 142 | 55 | 47 |
| Malaysia | 54 | 134 | 71 | 111 | 93 | 132 |
| Mongolia | 85 | 114 | 119 | 91 | 92 | 87 |
| Nepal | 82 | 110 | 104 | 91 | 105 | 99 |
| Oman | X | X | X | X | X | X |
| Pakistan | 69 | 133 | 90 | 104 | 100 | 98 |
| Philippines | 65 | 132 | 86 | 108 | 114 | 112 |
| Qatar | X | X | X | X | X | X |
| Saudi Arabia | 56 | 135 | 84 | 94 | 67 | 34 |
| Singapore | 50 | 94 | 44 | 86 | 36 | 39 |
| Sri Lanka | 69 | 140 | 84 | 121 | 82 | 83 |
| Syrian Arab Rep | 62 | 163 | 88 | 124 | 93 | 93 |
| Thailand | 66 | 136 | 90 | 113 | 118 | 133 |
| Turkey | 73 | 123 | 92 | 104 | 100 | 103 |
| United Arab Emirates | X | X | X | X | X | X |
| Viet Nam | 87 | 148 | 111 | 123 | 89 | 93 |
| Yemen | 87 | 104 | 103 | 88 | 94 | 80 |
| Yemen, Dem | 74 | 100 | 91 | 82 | 57 | 60 |
| **EUROPE** | | **115** | | **111** | **91** | **92** |
| Albania | 70 | 128 | 91 | 106 | 94 | 100 |
| Austria | 84 | 115 | 86 | 115 | 92 | 95 |
| Belgium | 79 | 104 | 87 | 103 | 75 | 75 |
| Bulgaria | 81 | 121 | 90 | 119 | 102 | 96 |
| Czechoslovakia | 74 | 122 | 82 | 117 | 90 | 94 |
| Denmark | 100 | 127 | 104 | 126 | 103 | 108 |
| Finland | 87 | 103 | 87 | 100 | 97 | 98 |
| France | 87 | 115 | 93 | 111 | 112 | 118 |
| German Dem Rep | 79 | 106 | 76 | 107 | 88 | 84 |
| Germany, Fed Rep | 88 | 115 | 90 | 116 | 83 | 86 |
| Greece | 69 | 113 | 76 | 104 | 98 | 95 |
| Hungary | 72 | 127 | 75 | 125 | 101 | 107 |
| Ireland | 77 | 111 | 78 | 101 | 96 | 100 |
| Italy | 86 | 114 | 91 | 111 | 83 | 82 |
| Luxembourg | X | X | X | X | X | X |
| Malta | 69 | 144 | 75 | 132 | 34 | 30 |
| Netherlands | 68 | 125 | 77 | 119 | 80 | 76 |
| Norway | 92 | 120 | 94 | 116 | 81 | 81 |
| Poland | 78 | 101 | 88 | 94 | 97 | 86 |
| Portugal | 86 | 89 | 99 | 85 | 83 | 57 |
| Romania | 67 | 126 | 77 | 119 | 105 | 100 |
| Spain | 65 | 115 | 77 | 107 | 90 | 89 |
| Sweden | 94 | 115 | 89 | 113 | 101 | 104 |
| Switzerland | 83 | 116 | 89 | 114 | 63 | 66 |
| United Kingdom | 91 | 124 | 88 | 124 | 70 | 79 |
| Yugoslavia | 76 | 119 | 82 | 111 | 101 | 96 |
| **USSR** | **76** | **107** | **85** | **100** | **100** | **92** |
| **OCEANIA** | | **117** | | **103** | **159** | **174** |
| Australia | 78 | 117 | 90 | 104 | 170 | 192 |
| Fiji | 95 | 136 | 121 | 118 | 169 | 153 |
| New Zealand | 80 | 114 | 89 | 110 | 129 | 130 |
| Papua New Guinea | 79 | 122 | 102 | 96 | 115 | 112 |
| Solomon Islands | 86 | 166 | 117 | 124 | 136 | 161 |
| **ANTARCTICA** | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 5.4 LAND DISTRIBUTION, 1960-80

| | Agricultural Holdings: Distribution by Size of Holdings (percent) | | | | | | | | | Agricultural Area: Distribution by Size of Holdings (percent) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | | | 1970 | | | 1980 | | | 1960 | | | 1970 | | | 1980 | | |
| | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha |
| **WORLD** | | | | | | | | | | | | | | | | | | |
| **AFRICA** | | | | | | | | | | | | | | | | | | |
| Algeria | X | X | X | 69 | 30 | 1 | X | X | X | X | X | X | 14 | 63 | 23 | X | X | X |
| Angola | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Benin | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Botswana | X | X | X | 74 | 26 | 0 | X | X | X | X | X | X | 26 | 74 | 0 | X | X | X |
| Burkina Faso | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Burundi | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Cameroon | X | X | X | 97 | 4 | 0 | X | X | X | X | X | X | 84 | 16 | 0 | X | X | X |
| Cape Verde | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Central African Rep | X | X | X | 98 | 3 | 0 | X | X | X | X | X | X | 90 | 10 | 0 | X | X | X |
| Chad | X | X | X | 89 | 11 | 0 | X | X | X | X | X | X | 72 | 28 | 0 | X | X | X |
| Comoros | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Congo | X | X | X | 99 | 1 | 0 | X | X | X | X | X | X | 98 | 2 | 0 | X | X | X |
| Djibouti | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Egypt | 90 | 10 | 0 | X | X | X | X | X | X | 51 | 34 | 16 | X | X | X | X | X | X |
| Equatorial Guinea | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Ethiopia | X | X | X | X | X | X | 96 | 4 | 0 | X | X | X | X | X | X | 82 | 18 | 0 |
| Gabon | X | X | X | 100 | 0 | 0 | X | X | X | X | X | X | 100 | 0 | 0 | X | X | X |
| Gambia | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Ghana | X | X | X | 86 | 14 | 0 | X | X | X | X | X | X | 47 | 54 | 0 | X | X | X |
| Guinea | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Guinea-Bissau | 85 | 16 | 0 | X | X | X | X | X | X | 61 | 39 | 0 | X | X | X | X | X | X |
| Ivory Coast | X | X | X | 64 | 36 | 0 | X | X | X | X | X | X | 32 | 68 | 1 | X | X | X |
| Kenya | 74 | 25 | 1 | 90 | 10 | 0 | X | X | X | 14 | 21 | 65 | 38 | 18 | 43 | X | X | X |
| Lesotho | 94 | 6 | 0 | 96 | 4 | 0 | X | X | X | 77 | 23 | 0 | 84 | 16 | 0 | X | X | X |
| Liberia | X | X | X | 93 | 7 | 0 | X | X | X | X | X | X | 36 | 35 | 29 | X | X | X |
| Libya | 24 | 62 | 14 | X | X | X | X | X | X | 2 | 35 | 63 | X | X | X | X | X | X |
| Madagascar | 97 | 3 | 0 | X | X | X | X | X | X | 89 | 11 | 0 | X | X | X | X | X | X |
| Malawi | X | X | X | 100 | 0 | 0 | X | X | X | X | X | X | 100 | 0 | 0 | X | X | X |
| Mali | 68 | 32 | 0 | X | X | X | X | X | X | 37 | 63 | 0 | X | X | X | X | X | X |
| Mauritania | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Mauritius | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Morocco | 75 | 25 | 0 | X | X | X | X | X | X | 38 | 62 | 0 | X | X | X | X | X | X |
| Mozambique | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Niger | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Nigeria | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Rwanda | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Senegal | 72 | 28 | 0 | X | X | X | X | X | X | 41 | 59 | 0 | X | X | X | X | X | X |
| Sierra Leone | X | X | X | 94 | 6 | 0 | X | X | X | X | X | X | 80 | 20 | 0 | X | X | X |
| Somalia | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| South Africa | 5 | 19 | 76 | X | X | X | X | X | X | 0 | 0 | 100 | X | X | X | X | X | X |
| Sudan | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Swaziland | X | X | X | 87 | 13 | 0 | X | X | X | X | X | X | 8 | 6 | 85 | X | X | X |
| Tanzania, United Rep | X | X | X | 95 | 5 | 0 | X | X | X | X | X | X | 79 | 21 | 0 | X | X | X |
| Togo | 87 | 13 | 0 | 97 | 3 | 0 | X | X | X | 57 | 43 | 0 | 74 | 27 | 0 | X | X | X |
| Tunisia | 41 | 55 | 4 | X | X | X | X | X | X | 6 | 54 | 40 | X | X | X | X | X | X |
| Uganda | 75 | 25 | 0 | X | X | X | X | X | X | 43 | 57 | 0 | X | X | X | X | X | X |
| Zaire | X | X | X | 99 | 1 | 0 | X | X | X | X | X | X | 60 | 5 | 35 | X | X | X |
| Zambia | 0 | 14 | 86 | 94 | 6 | 0 | X | X | X | 0 | 0 | 100 | 34 | 19 | 47 | X | X | X |
| Zimbabwe | 0 | 9 | 91 | X | X | X | X | X | X | 0 | 0 | 100 | X | X | X | X | X | X |
| **NORTH AMERICA** | | | | | | | | | | | | | | | | | | |
| Barbados | 81 | 7 | 13 | X | X | X | X | X | X | 6 | 5 | 89 | X | X | X | X | X | X |
| Canada | 4 | 30 | 66 | 5 | 24 | 72 | X | X | X | 0 | 7 | 93 | 0 | 3 | 97 | X | X | X |
| Costa Rica | 39 | 48 | 15 | 49 | 37 | 15 | X | X | X | 2 | 22 | 76 | 2 | 18 | 80 | X | X | X |
| Cuba | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Dominican Rep | 86 | 13 | 1 | 77 | 21 | 2 | X | X | X | 21 | 31 | 48 | 13 | 30 | 57 | X | X | X |
| El Salvador | 85 | 13 | 2 | 89 | 10 | 1 | X | X | X | 15 | 28 | 57 | 20 | 31 | 49 | X | X | X |
| Guatemala | 74 | 24 | 3 | X | X | X | X | X | X | 13 | 24 | 63 | X | X | X | X | X | X |
| Haiti | X | X | X | 96 | 4 | 0 | X | X | X | X | X | X | 78 | 23 | 0 | X | X | X |
| Honduras | X | X | X | 64 | 32 | 4 | X | X | X | X | X | X | 9 | 35 | 56 | X | X | X |
| Jamaica | 90 | 10 | 1 | 94 | 6 | 0 | X | X | X | 23 | 23 | 54 | 29 | 19 | 52 | X | X | X |
| Mexico | 66 | 22 | 12 | 60 | 26 | 14 | X | X | X | 1 | 3 | 96 | 1 | 4 | 96 | X | X | X |
| Nicaragua | 40 | 43 | 16 | X | X | X | X | X | X | 2 | 18 | 79 | X | X | X | X | X | X |
| Panama | 46 | 47 | 6 | 56 | 37 | 8 | 66 | 27 | 7 | 5 | 37 | 58 | 4 | 33 | 64 | 4 | 30 | 66 |
| Trinidad and Tobago | 72 | 27 | 2 | X | X | X | X | X | X | 20 | 34 | 46 | X | X | X | X | X | X |
| United States | 8 | 45 | 47 | 7 | 39 | 54 | X | X | X | 0 | 9 | 91 | 0 | 6 | 94 | X | X | X |
| **SOUTH AMERICA** | | | | | | | | | | | | | | | | | | |
| Argentina | 15 | 39 | 47 | X | X | X | X | X | X | 0 | 2 | 98 | X | X | X | X | X | X |
| Bolivia | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Brazil | 31 | 51 | 19 | 37 | 47 | 16 | X | X | X | 1 | 13 | 86 | 1 | 14 | 85 | X | X | X |
| Chile | 38 | 44 | 18 | X | X | X | X | X | X | 1 | 5 | 94 | X | X | X | X | X | X |
| Colombia | 63 | 31 | 7 | 60 | 32 | 8 | X | X | X | 5 | 20 | 76 | 4 | 19 | 78 | X | X | X |
| Ecuador | X | X | X | 67 | 27 | 7 | X | X | X | X | X | X | 7 | 28 | 65 | X | X | X |
| Guyana | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Paraguay | 44 | 51 | 6 | X | X | X | X | X | X | 1 | 7 | 92 | X | X | X | X | X | X |
| Peru | 84 | 14 | 2 | 78 | 20 | 2 | X | X | X | 6 | 8 | 86 | 7 | 14 | 79 | X | X | X |
| Suriname | 81 | 19 | 0 | 81 | 19 | 0 | X | X | X | 24 | 27 | 49 | 28 | 28 | 45 | X | X | X |
| Uruguay | 15 | 50 | 36 | 14 | 48 | 38 | 12 | 46 | 42 | 0 | 5 | 95 | 0 | 4 | 96 | 0 | 4 | 96 |
| Venezuela | 50 | 40 | 10 | 44 | 43 | 14 | X | X | X | 1 | 7 | 92 | 1 | 7 | 93 | X | X | X |

# Table 5.4

| | Agricultural Holdings: Distribution by Size of Holdings (percent) | | | | | | | | | Agricultural Area: Distribution by Size of Holdings (percent) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | | | 1970 | | | 1980 | | | 1960 | | | 1970 | | | 1980 | | |
| | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha | less than 5 ha | 5-50 ha | more than 50 ha |
| **ASIA** | | | | | | | | | | | | | | | | | | |
| Afghanistan | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Bahrain | X | X | X | 100 | 0 | 0 | 72 | 28 | 0 | X | X | X | 35 | 63 | 3 | 33 | 62 | 83 |
| Bangladesh | X | X | X | X | X | X | 100 | 0 | 0 | X | X | X | X | X | X | 100 | 0 | 0 |
| Bhutan | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Burma | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| China | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Cyprus | X | X | X | X | X | X | 76 | 23 | 0 | X | X | X | X | X | X | 31 | 55 | 14 |
| India | 87 | 13 | 0 | 89 | 11 | 0 | X | X | X | 47 | 51 | 3 | 47 | 50 | 4 | X | X | X |
| Indonesia | 98 | 3 | 0 | 98 | 2 | 0 | X | X | X | 67 | 21 | 12 | 69 | 18 | 14 | X | X | X |
| Iran | 53 | 46 | 1 | X | X | X | X | X | X | 17 | 69 | 14 | X | X | X | X | X | X |
| Iraq | 57 | 36 | 7 | 49 | 49 | 2 | X | X | X | 2 | 19 | 79 | 8 | 66 | 26 | X | X | X |
| Israel | X | X | X | 68 | 30 | 3 | X | X | X | X | X | X | 12 | 30 | 58 | X | X | X |
| Japan | 98 | 2 | 0 | 99 | 2 | 0 | 98 | 2 | 0 | 84 | 16 | 0 | 83 | 17 | 0 | 79 | 21 | 0 |
| Jordan | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Kampuchea, Dem | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Korea, Dem People's Rep | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Korea, Rep | 100 | 0 | 0 | 100 | 0 | 0 | X | X | X | 100 | 0 | 0 | 100 | 0 | 0 | X | X | X |
| Kuwait | X | X | X | 74 | 23 | 3 | X | X | X | X | X | X | 13 | 47 | 37 | X | X | X |
| Lao People's Dem Rep | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Lebanon | 80 | 20 | 1 | 82 | 17 | 1 | X | X | X | 39 | 45 | 17 | 22 | 43 | 35 | X | X | X |
| Malaysia | 89 | 10 | 1 | X | X | X | X | X | X | 30 | 14 | 56 | X | X | X | X | X | X |
| Mongolia | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Nepal | X | X | X | 97 | 3 | 0 | X | X | X | X | X | X | 72 | 27 | 1 | X | X | X |
| Oman | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Pakistan | 80 | 20 | 0 | 68 | 31 | 1 | 73 | 26 | 0 | 32 | 68 | 0 | 30 | 58 | 11 | 34 | 57 | 9 |
| Philippines | 81 | 19 | 0 | 85 | 15 | 0 | X | X | X | 43 | 45 | 12 | 48 | 38 | 14 | X | X | X |
| Qatar | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Saudi Arabia | X | X | X | 77 | 20 | 2 | X | X | X | X | X | X | 15 | 39 | 46 | X | X | X |
| Singapore | X | X | X | 100 | 0 | 0 | X | X | X | X | X | X | 98 | 0 | 0 | X | X | X |
| Sri Lanka | 97 | 3 | 0 | 98 | 2 | 0 | X | X | X | 53 | 20 | 28 | 58 | 42 | 0 | X | X | X |
| Syrian Arab Rep | X | X | X | 62 | 36 | 3 | X | X | X | X | X | X | 11 | 57 | 32 | X | X | X |
| Thailand | 72 | 28 | 0 | X | X | X | 72 | 28 | 0 | 43 | 57 | 0 | X | X | X | 39 | 61 | 0 |
| Turkey | 58 | 41 | 1 | X | X | X | 62 | 37 | 1 | 22 | 65 | 13 | X | X | X | 21 | 71 | 8 |
| United Arab Emirates | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Viet Nam | 89 | 11 | 0 | X | X | X | X | X | X | 61 | 29 | 11 | X | X | X | X | X | X |
| Yemen | X | X | X | X | X | X | 89 | 11 | 0 | X | X | X | X | X | X | 44 | 52 | 5 |
| Yemen, Dem | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| **EUROPE** | | | | | | | | | | | | | | | | | | |
| Albania | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Austria | 42 | 53 | 5 | 41 | 54 | 5 | X | X | X | 5 | 45 | 51 | 5 | 47 | 49 | X | X | X |
| Belgium | 62 | 37 | 1 | 53 | 46 | 1 | 44 | 53 | 3 | 16 | 73 | 11 | 10 | 77 | 13 | 6 | 74 | 20 |
| Bulgaria | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Czechoslovakia | X | X | X | 98 | 2 | 1 | 90 | 10 | 0 | X | X | X | 7 | 5 | 88 | 7 | 6 | 87 |
| Denmark | 19 | 78 | 3 | 10 | 84 | 7 | 14 | 77 | 9 | 4 | 78 | 18 | 1 | 73 | 26 | 2 | 63 | 35 |
| Finland | 53 | 47 | 0 | 36 | 63 | 1 | X | X | X | 28 | 68 | 4 | 53 | 46 | 1 | X | X | X |
| France | 29 | 65 | 6 | 31 | 61 | 8 | 28 | 60 | 12 | 5 | 67 | 29 | 5 | 62 | 34 | 4 | 54 | 42 |
| German Dem Rep | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Germany, Fed Rep | 55 | 44 | 1 | 39 | 59 | 2 | X | X | X | 17 | 71 | 12 | 9 | 77 | 14 | X | X | X |
| Greece | X | X | X | 80 | 21 | 0 | X | X | X | X | X | X | 45 | 53 | 3 | X | X | X |
| Hungary | X | X | X | 99 | 0 | 0 | 100 | 0 | 0 | X | X | X | 5 | 0 | 95 | 3 | 0 | 74 |
| Ireland | 17 | 76 | 7 | 20 | 73 | 7 | X | X | X | 3 | 65 | 32 | 3 | 65 | 32 | X | X | X |
| Italy | 76 | 23 | 1 | 76 | 23 | 1 | X | X | X | 20 | 43 | 36 | 18 | 40 | 42 | X | X | X |
| Luxembourg | X | X | X | 25 | 63 | 13 | X | X | X | X | X | X | 3 | 83 | 14 | X | X | X |
| Malta | 75 | 25 | 0 | 91 | 9 | 0 | 97 | 3 | 0 | 77 | 23 | 0 | 77 | 23 | 0 | 83 | 17 | 0 |
| Netherlands | 54 | 46 | 1 | 35 | 64 | 1 | X | X | X | 12 | 79 | 9 | 6 | 85 | 9 | X | X | X |
| Norway | 69 | 31 | 0 | 57 | 43 | 1 | X | X | X | 42 | 56 | 2 | 34 | 64 | 2 | X | X | X |
| Poland | 63 | 37 | 0 | 62 | 38 | 0 | X | X | X | 24 | 61 | 15 | 26 | 74 | 0 | X | X | X |
| Portugal | X | X | X | 82 | 17 | 1 | X | X | X | X | X | X | 18 | 31 | 51 | X | X | X |
| Romania | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Spain | 50 | 45 | 5 | X | X | X | X | X | X | 6 | 29 | 65 | X | X | X | X | X | X |
| Sweden | 37 | 60 | 3 | 26 | 67 | 7 | X | X | X | 10 | 68 | 22 | 16 | 64 | 21 | X | X | X |
| Switzerland | X | X | X | 45 | 54 | 1 | X | X | X | X | X | X | 45 | 67 | 71 | X | X | X |
| United Kingdom | 32 | 49 | 19 | 22 | 52 | 26 | X | X | X | 2 | 24 | 74 | 1 | 20 | 79 | X | X | X |
| Yugoslavia | 71 | 29 | 0 | 74 | 26 | 0 | X | X | X | 33 | 57 | 11 | 33 | 48 | 19 | X | X | X |
| **USSR** | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| **OCEANIA** | | | | | | | | | | | | | | | | | | |
| Australia | 7 | 25 | 69 | 8 | 24 | 69 | X | X | X | 0 | 0 | 100 | 0 | 0 | 100 | X | X | X |
| Fiji | X | X | X | 58 | 42 | 0 | 85 | 14 | 1 | X | X | X | 13 | 87 | 0 | 17 | 41 | 42 |
| New Zealand | 3 | 36 | 61 | 5 | 29 | 67 | X | X | X | 0 | 4 | 96 | 0 | 3 | 98 | X | X | X |
| Papua New Guinea | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Solomon Islands | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | | | | | | | | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = data not available.
For additional information, see Sources and Technical Notes.

# Table 5.5 CROPLAND SOIL EROSION IN SELECTED COUNTRIES, 1970s AND 1980s

| | Extent and Location | Affected Area as Percentage of Total Area | Amount of Erosion (metric tons per year) | Rate of Erosion (metric tons per hectare per year) | Year of Estimate |
|---|---|---|---|---|---|
| Ethiopia | Central Highland Plateau (47 million ha) | 43 | 1.6 billion | 34 | 1970s |
| Lesotho | Grazing and Arable Lands (2.7 million ha) | 88 | 18.5 million | 7 | X |
| Niger | Small Watershed (11,700 ha) | 0.01 | 468 thousand | 40 | X |
| Nigeria | State of Imo (900,000 ha) | 1 | 13 million | 14.4 | 1974 |
| Madagascar | Mostly Cropland (45.9 million ha) | 79 | X | 25–250 | 1970s |
| Zimbabwe | Area with Moderate to Severe Erosion (304,000 ha) | 0.8 | 15 million | 50 | 1979 |
| Guatemala | Western Highlands | X | X | 5–35 | 1979 |
| Jamaica | Upper Yalluhs Valley | X | X | 90 | X |
| United States | Total Cropland (169 million ha) | 19 | 1.66 billion | 9.6 | 1982 |
| Argentina, Paraguay, and Brazil | La Plata River Basin | X | 95 million | 18.8 | X |
| Ecuador | High Sierra | X | X | 210–564 | X |
| Peru | Entire Country (128 million ha) | 100 | 1.9 billion | 15 | X |
| China | Loess Plateau Region (60 million ha) | 6.4 | X | 11–251 | 1980 |
| India | Seriously Affected Cropland (80 million ha) | 27 | 6 billion | 75 | 1975 |
| Nepal | Entire Country (13.7 million ha) | 100 | 240 million | 35–70 | X |
| Belgium | Central Belgium | X | X | 10–25 | 1970s |

**Source:** World Resources Institute, International Institute for Environment and Development.
X = not available.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 5.1 Agricultural Production, 1964–84

**Sources:** Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Total agricultural production for 1982–84 and yields for 1974–76 and 1982–84: FAO, *Production Yearbook 1984* (FAO, Rome, 1985). Agricultural production per agricultural worker, 1982–84: FAO, unpublished data, 1985.

Indexes of agricultural production represent the disposable output (after deduction for feed and seed) of a country's agriculture sector relative to the base period 1974–76. The index for a given year is calculated as follows: the disposable output of a commodity in weight or volume terms is multiplied by the 1974–76 unit value of the commodity. The product of this equation is the total value of the crop for that year in terms of 1974–76 prices. The values of all crop and livestock products are totaled to derive the value of all agricultural production in 1974–76 prices. The aggregate output for other years is then divided by the aggregate output for 1974–76 and multiplied by 100 to obtain the index number.

Indexes for continents and the world are computed by converting national production figures in local currencies to U.S. dollar equivalents using International Monetary Fund (IMF) exchange rates. The country outputs are totaled to derive the regional and global aggregates.

Index numbers of agricultural production include all crop and livestock products originating in each country for which information is available. Agricultural labor data are collected by the International Labor Organization (ILO). See Chapter 1, "Basic Economic Indicators," introduction, and Table 1.2, Sources and Technical Notes.

Yields are calculated from national production and area data. Production data include cereal used as feed and seed. Area data relate to the area harvested rather than the area sown. Cereals refer to all cereals (wheat, maize, rice, etc.) harvested for dry grain, exclusive of crops cut for hay or harvested green. Roots and tubers refer to all root crops grown principally for human consumption (potatoes, cassava, yams, taro, etc.); root crops grown principally for feed (turnips, swedes, mangels) are excluded.

Most of the data in Tables 5.1, 5.2, 5.3, 5.4, and 4.1 (see Chapter 4) are supplied by national agriculture ministries in response to annual FAO questionnaires, or are derived from agricultural censuses. FAO compiles data from more than 200 countries and many other sources, and enters them into a computerized database. The database facilitates the calculation of analytical indicators such as agricultural and food production indexes and ratios of calorie self-sufficiency. However, many gaps exist in the data, which FAO fills by preparing its own estimates. As more information becomes available, FAO corrects its estimates and recalculates the whole time series as necessary.

Countries collect many kinds of information through agricultural censuses: the size and age distribution of the agricultural labor force; the amount of land planted in various crops; the degree of farm mechanization; the use of fertilizers, pesticides and irrigation, etc. Most of the aggregate data are broken down by size-classes of holdings. For example, of the 2.5 million wheat holdings counted in Turkey's 1980 census of agriculture, 53,000 were smaller than 0.5 hectares, and 637,000 were between 5 and 10 hectares. Similar data are reported for holdings of 1–2 hectares, 2–3 hectares, 3–4 hectares, 4–5 hectares, 10–20 hectares, 20–50 hectares, and 50–100 hectares.

FAO has conducted world censuses of agriculture in 1950, 1960, 1970, and 1980. The 1980 census is still in progress. FAO's predecessor, the International Institute of Agriculture, also conducted a census in 1930. The table below summarizes the number of countries that have participated in the 1960, 1970, and 1980 censuses of agriculture. The table includes former colonies whose censuses were conducted by the colonial administration. The table excludes countries that are not independent.

| | 1960 Census | 1970 Census | 1980 Census[a] Plan to Participate | Undecided or No Reply |
|---|---|---|---|---|
| Europe | 17 | 24 | 20 | 4 |
| North America[b] | 2 | 2 | 2 | 0 |
| Latin America | 19 | 24 | 19 | 10 |
| Near East[c] | 7 | 10 | 15 | 6 |
| Far East | 13 | 10 | 10 | 9 |
| Africa[c] | 26 | 22 | 29 | 12 |
| Oceania | 4 | 3 | 4 | 1 |
| | 88 | 95 | 99 | 42 |

**Notes:**
a. Information as of May 1981. FAO sent an exploratory questionnaire in 1977 to 147 member countries. A second questionnaire was sent to 152 countries in May 1980. Replies received by May 1981 are included in this table.
b. United States and Canada.
c. Libya, Egypt, Sudan, Djibouti, and Somalia are included in Near East and excluded from Africa.

## Table 5.2 Agricultural Inputs, 1964–83

**Sources:** Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Arable and permanent cropland, irrigated land, and tractors, 1974–76 and 1981–83. FAO, *Production Yearbook 1983 and 1984* (FAO, Rome, 1984 and 1985). Fertilizer Consumption 1974–76: FAO, *Fertilizer Yearbook 1983* (FAO, Rome, 1984). Fertilizer consumption 1981–83: FAO, "Monthly Bulletin of Statistics," April 1985.

Arable and permanent cropland is defined in the technical note in Chapter 4, "Land Use and Cover"; see the Technical Note for Table 4.1. Irrigated land refers to areas purposely provided with water, including land flooded by river water for crop production or pasture improvement, whether this area is irrigated several times or only once during the year.

Fertilizer use refers to application of nutrients in terms of nitrogen (N), phosphate ($P_2O_5$) and potash ($K_2O$). The fertilizer year is July 1–June 30; for 1964–66, fertilizer use refers to the split years ending in 1964, 1965, and 1966. Data for 1974–76 are the average of the 1974–75 and 1975–76 fertilizer years. Data for 1981–83 are the average of the 1981–82 and 1982–83 fertilizer years.

Tractors refer to total wheel and crawler tractors used in agriculture; garden tractors are excluded.

Refer to the Technical Note for Table 5.1 for detailed information on data collection and analysis.

## Table 5.3 Food Production and Consumption, 1964–84

**Sources:** Data for 1964–66: U.N. Food and Agriculture Organization (FAO), unpublished data, 1985. Data for 1982–84: FAO, *Production Yearbook 1984* (FAO, Rome, 1985). Data for calories domestically produced as percentage of total supply: FAO, *Socio-economic Indicators Relating to the Agricultural Sector and Rural Development*, Economic and Social Development Paper 40 (FAO, Rome, 1984).

Indexes of food production are computed in the same manner as indexes of agricultural production. Refer to the Technical Note for Table 5.1 for details. The food production index covers the subset of agricultural crops that are edible and contain nutrients. Coffee and tea, although edible, are excluded from the food production index because they have virtually no nutritive value.

The proportion of the total calorie supply produced domestically is calculated from the Supply Utilization Accounts developed by FAO. The numerator of the fraction, calories domestically produced, is computed on a commodity-by-commodity basis from production data. The denominator is the sum of the domestic calorie production (the numerator); net imports of calories in foodstuffs, and the calories supplied by the net drawdown of food stocks.

Refer to the Technical Note for Table 5.1 for detailed information on data collection and analysis.

## Table 5.4 Land Distribution, 1960–80

**Sources:** Data for 1960: U.N. Food and Agriculture Organization (FAO), *Report on the 1960 World Census of Agriculture: Analysis and International Comparison of Results* (FAO, Rome, 1971). Data for 1970: FAO, *1970 World Census of Agriculture: Analysis and International Comparison of Results* (FAO, Rome, 1981). Data for 1980: FAO, *Report on the 1980 World Census of Agriculture*, Census Bulletins 2–13, October 1983–May 1985.

The years 1960, 1970, and 1980 refer to the World Censuses of Agriculture organized by FAO. Data for 1960 were compiled from national censuses conducted between 1958 and 1964. The 1970 round of censuses covered the period 1966 to 1974. The 1980 census round will include national censuses conducted between 1977 and 1985, with the majority falling between 1979 and 1981. The specific dates of country censuses are reported in the sources. Refer to the Technical Note for Table 5.1 for details of participation in the three most recent censuses.

An agricultural holding, as defined in the *World Census of Agriculture*, is a unit of agricultural production comprising all livestock kept and all land used wholly or partly for agricultural purposes. It may be operated by one person or more, regardless of title, legal form, size, or location. A holding may consist of one or more parcels of land, and may consist of livestock without agricultural land. Common grazing land is not considered a holding. Establishments producing only forest products, race horses, fish, frogs, dogs, or wild game are not considered holdings. Land rented from an owner is considered within the holding of the operator and outside the holding of the owner.

Agricultural area refers to all land under temporary or permanent crops and land used as permanent pasture. For detailed definitions, refer to Chapter 4, "Land Use and Cover"; see the Technical Note for Table 4.1.

FAO strives to achieve comparability of data across countries by circulating standard questionnaires; preparing detailed program documents; conducting regional training seminars, etc. However, to accommodate local circumstances, countries often deviate from the standard definitions and survey techniques, making comparisons across countries (or across years for the same country) difficult. For example, the censuses of many countries exclude holdings that are below some minimum size or economic importance. In 1960, France counted all holdings larger than 1 hectare or larger than 0.2 hectares if engaged in specialized agriculture. Zambia's census covered only European holdings larger than 10.11 hectares. Panama counted holdings larger than 0.5 hectares, but excluded approximately 8,300 holdings operated by indigenous populations.

In 1970 and 1980, France retained the same minimum size criteria. In 1970, Zambia's census covered the land under crops for the traditional sector and the total area of holdings for the modern sector. Panama's censuses for 1970 and 1980 counted holdings of any size, but did not include holdings in the indigenous zones. Refer to FAO's census publications for details concerning the coverage of censuses and the definitions and classifications used.

## Table 5.5 Cropland Soil Erosion in Selected Countries, 1970s and 1980s

**Sources:** Compiled by World Resources Institute and International Institute for Environment and Development from sources listed below.

- *Ethiopia:* U.N. Food and Agriculture Organization, *Protect and Produce: Soil Conservation for Development* (FAO, Rome, 1984), p. 17.
- *Lesotho:* Arid Lands Information Center, University of Arizona, *Draft Environmental Profile of the Kingdom of Lesotho* (University of Arizona, Tucson, Arizona, 1982), p. 77.
- *Niger:* S.A. El-Swaify, *et al.* "Soil Immersion by Water" in *Natural Systems for Development: What Planners Need to Know* (MacMillan Publishing Company, New York, 1983).
- *Nigeria:* G.E. Osuji, "The Gullies of Imo," *Journal of Soil and Water Conservation*, July-August 1984, Vol. 39, No. 4, pp. 246–247.
- *Madagascar:* P. Randrianarijaona, "The Erosion of Madagascar," *AMBIO*, Vol. 12, No. 6, pp. 308–311 (1983).
- *Zimbabwe:* Arid Lands Information Center, University of Arizona, *Draft Environmental Profile of Zimbabwe* (University of Arizona, Tucson, Arizona, 1982), p. 89.
- *Guatemala:* Institute of Ecology, University of Georgia, *An Environmental Profile of Guatemala* (University of Georgia, Athens, Georgia, 1981), p. 18.
- *Jamaica:* U.N. Food and Agriculture Organization (FAO), *Strengthening the National Soil Conservation Programme for Integrated Watershed Development, Jamaica,*

*Terminal Report* (FAO, Rome, 1982).

■ *United States:* Rosenberry and English in "Erosion Control Practices: Impact of Actual Versus Most Effective Use," in *Conservation Needs and Opportunities* (Board of Agriculture, National Research Council). Data were taken from the 1982 Natural Resources Inventory, U.S. Department of Agriculture, Soil Conservation Service.

■ *Argentina:* Organization of American States (OAS), *Cuenca del Rio de la Plata: Estudio para su Platificación y Desarollo* (OAS, Washington, D.C., 1974).

■ *Ecuador:* S.A. El-Swaify, *et al.* "Soil Immersion by Water," in *Natural Systems for Development: What Planners Need to Know* (MacMillian Publishing Company, New York, 1983).

■ *Peru:* Interview with Lorenzo Chang Novarro (Director of Peru's Department of Watershed, Soil, and Water Conservation) in Abraham Lama, "Peru: Rapid Soil Erosion Threatens Peruvian Agriculture," *Latin America Links*, 1984.

■ *China:* Lee Hsiao-tseng, "Soil Conservation in China's Loess Plateau," *Journal of Soil and Water Conservation*, Vol. 39 No. 4 (1984), pp. 306–307. Zhu Ling "Study Aims to Lift Flood Threat of Yellow River," *China Daily*, Vol. 4, No. 1069 (1984).

■ *India:* Das, "Soil Conservation Practices and Erosion Control in India—A Case Study," *Soils Bulletin*, No. 33 (FAO, Rome, 1977).

■ *Nepal:* Science and Technology Division, Library of Congress, *Draft Environmental Report on Nepal* (Library of Congress, Washington, D.C., 1979), p. 43.

■ *Belgium:* G. Richter, "Aspects and Problems of Erosion Hazard in the EEC Countries," in *Soil Erosion* (Commission of the European Communities, Luxembourg, 1982), p. 11.

Soil erosion is the removal of soil from the land by the erosive processes of moving water and wind. There are two main types of water erosion: "sheet erosion," which occurs when beating rain and flowing water remove thin layers of soil from a field, and "rill erosion," which occurs as flowing water carves out channels in the soil.

The natural rate of erosion is determined by climate, topography, soil type, and vegetative cover. It can be exacerbated by poor agricultural practices, overgrazing of livestock, and deforestation. On large areas of cropland the loss of top soil is greater than the amount added naturally, and as a result the land becomes less fertile and less productive.

There are three locations within a watershed at which soil erosion rates can be estimated. The "upstream methods" estimate the amount of erosion based on field observations. The "midstream methods" estimate the volume of soil erosion based on the sediment loads carried by rivers and other watercourses. The "downstream methods" estimate the severity of soil erosion based on the volume of sediment deposited in lakes, reservoirs, or at the drainage point of a water basin.

Erosion rates are not strictly comparable across countries because different methods of estimation have been used and most of the sources did not identify which type of estimation method was used. Countries measure erosion differently depending on the causes of the problem and on the techniques and methods employed. In the United States, erosion from wind and/or rain was estimated depending on the location sampled. In Madagascar, where the problems of erosion are caused by heavy rainfall, only water erosion was estimated.

There are other important caveats concerning the data:

1. Most of the field measurements of erosion rates have been carried out in areas where sheet and rill erosion is most serious: parts of North and South America, India, and China. Much less has been done to measure wind erosion in the arid and semi-arid lands of sub-Saharan Africa and Southern Africa.
2. Some of the data in the table are point estimates, based on a few measurements made at one point in time and extrapolated to reflect an annual average.
3. An attempt has been made to choose countries and sites where soil erosion can be associated with agricultural practices. However, no attempt has been made to correct soil erosion estimates for the amounts of soil eroded by factors unrelated to cultivation of cropland.

For a recent and detailed review of soil erosion in developing countries, see Alfredo Sfeir-Younis, *Soil Conservation in Developing Countries*, (The World Bank, unpublished manuscript, Washington, D.C., 1985).

# 6. Forests and Rangelands

Forests and rangelands together occupy roughly three-quarters of the world's land surface. However, the statistics available with which to evaluate changes in these lands are weak, particularly when compared to information on cultivated lands.

Some of the best data on forests are for areas that are extensive and remote, such as the vast forested areas of Canada, the Soviet Union, Zaire, and Brazil, which can be monitored from satellites, or for actively managed areas such as plantations. Statistics are least available where they are most needed: in developing countries without the resources to monitor and manage forests and where competing demands for cropland, fuelwood, and industrial timber are rapidly changing the forests.

Table 6.1 provides information on the extent, change, and management of forests. The definitions and techniques used to measure forests greatly influence the numbers shown. For example, the trees of a closed forest fully shade the ground, preventing the growth of grasses. In an open forest, trees cover at least 10 percent of the ground, permitting a nearly continuous grass layer on the forest floor. (Areas meeting this description are classified as rangeland in some countries.)

Omitted from the table are forest fallow, about 400 million hectares of land that is cut, burned, and cultivated for a year or two and then allowed to return to trees until the next slash and burn cycle. Also omitted are 600 million hectares of shrubland. In densely settled rural areas, closed forests may have been largely degraded or even eliminated and replaced by shrubs that are important sources of fuelwood, forage, and other products.

Deforestation is often defined imprecisely. In Table 6.1 it refers to the clearing of closed forested land and its subsequent use for agriculture or settlement. Other alterations, such as logging of closed forests, or active management of productive stands, are not considered deforestation.

Forest management is the active management of forest growth or regeneration in accordance with a plan. Such plans include logging controls, fire and disease prevention and treatment, and sylvicultural research. Protected areas are legally defined forests in national or scientific parks where timber exploitation is forbidden.

Countries with the largest areas of forest are the Soviet Union, Brazil, Canada, the United States, China, and Indonesia. Those with the highest estimated rates of deforestation are Ivory Coast, Paraguay, Nigeria, Costa Rica, and Nepal. Although a deforestation rate of less than 1 percent per year is small in relative terms, in countries such as Brazil, India, and Indonesia, even that rate can mean extensive loss of forest land.

There has been considerable controversy over the estimates of tropical deforestation. Global reviews conducted in the early 1970s, for example, found less tropical forest and higher rates of deforestation than those shown here. The different estimates can be attributed largely to different definitions and measurement techniques. The figures in Table 6.1, collected in the late 1970s and first published in 1981, may not reflect current conditions.

Table 6.2 provides measures of wood harvests, as well as estimates of the economic value of forest products that enter into international trade. The figures reveal important shifts: Brazil and Malaysia have dramatically increased exports; Egypt has dramatically increased imports; and Nigeria has shifted from a net exporter to a net importer.

Missing from these tables are a number of data series that would be useful to policymakers, foresters, and landowners who need to plan the future use of forest land. Among these are the volume of economically valuable trees for timber production, changes in forest conditions and composition of flora and fauna, and better information on forest management.

Table 6.3 presents statistics on desertification, based on a global review carried out for the United Nations Environment Program (UNEP). The percentage figures (which should be regarded as informed estimates) indicate the amount of land that is believed to be reduced in productivity by 25 percent or more from its original condition. The Sudano-Sahelian region, which has experienced a decline in precipitation and an increase in livestock grazing over the past 30 years, reports increasing desertification. More importantly, 14 of the 19 countries surveyed reported increases in rates of desertification; 5 of the 14 reported significant increases. Desertification pressures are greatest on rangelands and recently deforested lands.

# Table 6.1 FOREST RESOURCES, 1980s

| | Extent of Forest and Woodland, 1980 (thousand hectares) | | Deforestation of Closed Forests, 1981–85 | | Reforestation 1980s (thousand hectares per year) | Managed Closed Forests 1980 (thousand hectares) | Protected Forest Areas 1980 (thousand hectares) |
|---|---|---|---|---|---|---|---|
| | Open | Closed | Average Annual Extent (thousand hectares per year) | Percent per Year | | | |
| **WORLD** | **1352460** | **2936693** | | | | | |
| **AFRICA** | **489374** | **235805** | | | | | |
| Algeria | 2500 | 490 | X | X | X | X | X |
| Angola | 50700 | 4471 | 44 | 1.0 | 0 | X | X |
| Benin | 3820 | 47 | 1 | 2.6 | 0 | X | X |
| Botswana | 32560 | 0 | X | X | X | X | X |
| Burkina Faso | 7200 | 120 | X | X | 2 | X | X |
| Burundi | 14 | 222 | 1 | 0.3 | 1 | X | 16 |
| Cameroon | 7700 | 18105 | 80 | 0.4 | 1 | X | X |
| Cape Verde | 0 | 1 | X | X | X | X | X |
| Central African Rep | 32300 | 3595 | 5 | 0.1 | 0 | X | X |
| Chad | 13000 | 532 | X | X | 1 | X | X |
| Comoros | X | X | X | X | X | X | X |
| Congo | 0 | 21508 | 22 | 0.1 | 2 | X | 130 |
| Djibouti | 100 | 6 | X | X | X | X | X |
| Egypt | 30 | 1 | X | X | X | X | X |
| Equatorial Guinea | 0 | 1295 | 3 | 0.2 | 0 | X | X |
| Ethiopia | 22800 | 5332 | 8 | 0.2 | 6 | X | X |
| Gabon | 75 | 20690 | 15 | 0.1 | 0 | X | X |
| Gambia | 150 | 78 | 2 | 2.8 | X | X | X |
| Ghana | 6975 | 2471 | 22 | 0.9 | 3 | 1167 | 397 |
| Guinea | 8600 | 2072 | 36 | 1.7 | X | X | X |
| Guinea-Bissau | 1445 | 664 | 17 | 2.6 | X | X | X |
| Ivory Coast | 5376 | 4907 | 290 | 5.9 | 3 | 1 | 648 |
| Kenya | 1255 | 2605 | 19 | 0.7 | 7 | 70 | 570 |
| Lesotho | 0 | 0 | X | X | X | X | X |
| Liberia | 40 | 2063 | 46 | 2.2 | 1 | X | X |
| Libya | 390 | 70 | X | X | X | X | X |
| Madagascar | 2900 | 12960 | 150 | 1.2 | 12 | X | 930 |
| Malawi | 4085 | 989 | X | X | 6 | X | 146 |
| Mali | 8800 | 19 | X | X | 0 | X | X |
| Mauritania | 15000 | 0 | X | X | X | X | X |
| Mauritius | 29 | 2 | X | X | X | X | X |
| Morocco | 4800 | 400 | X | X | 20 | X | X |
| Mozambique | 14500 | 1189 | 10 | 0.8 | 1 | X | 25 |
| Niger | 2900 | 60 | X | X | 1 | X | X |
| Nigeria | 8800 | 7583 | 300 | 4.0 | 14 | X | X |
| Rwanda | 110 | 412 | 3 | 0.8 | 2 | X | 16 |
| Senegal | 10825 | 345 | X | X | 2 | X | 63 |
| Sierra Leone | 1315 | 798 | 6 | 0.8 | 0 | X | X |
| Somalia | 7510 | 1650 | 4 | 0.2 | 2 | X | X |
| South Africa | 2800 | 1350 | X | X | X | X | X |
| Sudan | 47000 | 2532 | 4 | 0.2 | 11 | 50 | X |
| Swaziland | 50 | 100 | X | X | X | X | X |
| Tanzania, United Rep | 40600 | 2658 | 10 | 0.4 | 7 | X | 410 |
| Togo | 1380 | 304 | 2 | 0.7 | 0 | X | X |
| Tunisia | 350 | 400 | X | X | X | X | X |
| Uganda | 5250 | 879 | 10 | 1.1 | 1 | 442 | 58 |
| Zaire | 71840 | 105975 | 182 | 0.2 | X | X | 5700 |
| Zambia | 26500 | 3390 | 40 | 1.2 | 3 | 5 | 220 |
| Zimbabwe | 15000 | 465 | X | X | X | X | X |
| **NORTH AMERICA** | **275320** | **530451** | | | | | |
| Barbados | X | X | X | X | X | X | X |
| Canada | 172300 | 264100 | X | X | 720 | X | 4870 |
| Costa Rica | X | 1664 | 65 | 3.9 | 0 | X | 320 |
| Cuba | 0 | 3025 | 2 | 0.1 | 11 | 200 | X |
| Dominican Rep | 0 | 685 | 4 | 0.6 | 0 | X | X |
| El Salvador | 0 | 155 | 5 | 2.9 | 0 | X | X |
| Guatemala | X | 4596 | 90 | 2.0 | 3 | X | 62 |
| Haiti | 0 | 58 | 2 | 3.1 | 0 | X | X |
| Honduras | 200 | 3797 | 90 | 2.4 | 0 | 58 | X |
| Jamaica | 0 | 195 | 2 | 1.0 | 1 | X | 2 |
| Mexico | X | 47840 | 595 | 1.2 | 17 | X | 360 |
| Nicaragua | 0 | 4508 | 121 | 2.7 | 0 | 250 | X |
| Panama | 0 | 4204 | 36 | 0.9 | 1 | X | X |
| Trinidad and Tobago | 0 | 368 | 1 | 0.2 | 1 | 14 | X |
| United States | 102820 | 195256 | X | X | 1775 | 102362 | 31198 |
| **SOUTH AMERICA** | **247875** | **657670** | | | | | |
| Argentina | 32300 | 7670 | X | X | 38 | X | X |
| Bolivia | 22750 | 44013 | 87 | 0.2 | 0 | X | X |
| Brazil | 157000 | 396030 | 1480 | 0.4 | 346 | X | 4660 |
| Chile | 2430 | 6250 | X | X | 50 | X | X |
| Colombia | 5300 | 47351 | 820 | 1.7 | 8 | X | 2280 |
| Ecuador | X | 14679 | 340 | 2.3 | 4 | X | 350 |
| Guyana | 25 | 18487 | 3 | 0.0 | 0 | X | 12 |
| Paraguay | *26260* | *4100* | *190* | *4.6* | *0* | X | *90* |
| Peru | 1120 | 70520 | 270 | 0.4 | 4 | X | 850 |
| Suriname | 690 | 14915 | 3 | 0.0 | 0 | X | 580 |
| Uruguay | 0 | 580 | X | X | 5 | X | X |
| Venezuela | X | 33075 | 125 | 0.4 | 14 | X | 4500 |

# Table 6.1

| | Extent of Forest and Woodland, 1980 (thousand hectares) | | Deforestation of Closed Forests, 1981–85 | | Reforestation 1980s (thousand hectares per year) | Managed Closed Forests 1980 (thousand hectares) | Protected Forest Areas 1980 (thousand hectares) |
|---|---|---|---|---|---|---|---|
| | Open | Closed | Average Annual Extent (thousand hectares per year) | Percent per Year | | | |
| **ASIA** | **109408** | **497567** | | | | | |
| Afghanistan | 1300 | 200 | X | X | X | X | X |
| Bahrain | 0 | 0 | X | X | X | X | X |
| Bangladesh | 0 | 2207 | 8 | 0.4 | 9 | 795 | 52 |
| Bhutan | 40 | 2170 | 2 | 0.1 | 1 | X | X |
| Burma | 0 | 32101 | 105 | 0.3 | 2 | 3419 | 299 |
| China | 45000 | 125000 | X | X | 4552 | X | X |
| Cyprus | 24 | 153 | X | X | X | 153 | 25 |
| India | 5393 | 72521 | 147 | 0.2 | 120 | 32557 | 6779 |
| Indonesia | 3000 | 123235 | 600 | 0.5 | 187 | 40 | 5430 |
| Iran | 10500 | 1900 | X | X | X | X | X |
| Iraq | 1880 | 30 | X | X | X | X | X |
| Israel | 20 | 80 | X | X | 2 | 56 | 7 |
| Japan | 1390 | 23890 | X | X | 240 | X | X |
| Jordan | 28 | 54 | X | X | X | X | X |
| Kampuchea, Dem | 5100 | 7616 | 25 | 0.3 | 0 | X | X |
| Korea, Dem People's Rep | X | 8970 | X | X | 200 | X | X |
| Korea, Rep | 240 | 6275 | X | X | 152 | X | X |
| Kuwait | 0 | 15 | X | X | X | X | X |
| Lao People's Dem Rep | 5215 | 8520 | 100 | 1.2 | 1 | X | X |
| Lebanon | 50 | 35 | X | X | X | X | X |
| Malaysia | 0 | 21256 | 255 | 1.2 | 4 | 2499 | 959 |
| Mongolia | 5000 | 10000 | X | X | X | X | X |
| Nepal | 180 | 2128 | 84 | 3.9 | 2 | X | 330 |
| Oman | 0 | 0 | X | X | X | X | X |
| Pakistan | 295 | 3785 | 7 | 0.2 | 7 | 410 | 15 |
| Philippines | 0 | 12510 | 91 | 0.7 | 42 | X | 690 |
| Qatar | 0 | 0 | X | X | X | X | X |
| Saudi Arabia | 1200 | 0 | X | X | X | X | X |
| Singapore | X | X | X | X | X | X | X |
| Sri Lanka | X | 2782 | 58 | 2.1 | 10 | X | 193 |
| Syrian Arab Rep | 330 | 90 | X | X | 10 | X | X |
| Thailand | 6440 | 10375 | 252 | 2.4 | 13 | X | 2220 |
| Turkey | 11343 | 8856 | X | X | 82 | 8856 | 139 |
| United Arab Emirates | 0 | 3 | X | X | X | X | X |
| Viet Nam | 1340 | 10810 | 65 | 0.6 | 20 | 70 | 560 |
| Yemen | 2500 | 0 | X | X | X | X | X |
| Yemen, Dem | 1600 | 0 | X | X | X | X | X |
| **EUROPE** | **21787** | **137005** | | | | | |
| Albania | 0 | 1280 | X | X | X | X | X |
| Austria | 0 | 3754 | X | X | 21 | 1489 | 0 |
| Belgium | 80 | 682 | X | X | 19 | 272 | 0 |
| Bulgaria | 400 | 3328 | X | X | 50 | 3600 | 100 |
| Czechoslovakia | 145 | 4435 | X | X | 37 | 4435 | X |
| Denmark | 18 | 466 | X | X | X | 330 | 56 |
| Finland | 3340 | 19885 | X | X | 158 | 10578 | 294 |
| France | 1200 | 13875 | X | X | 51 | 2957 | 92 |
| German Dem Rep | 285 | 2700 | X | X | X | 2697 | 85 |
| Germany, Fed Rep | 218 | 6989 | X | X | 62 | 3886 | X |
| Greece | 3242 | 2512 | X | X | X | 1603 | 55 |
| Hungary | 25 | 1612 | X | X | 19 | 1612 | 41 |
| Ireland | 33 | 347 | X | X | 9 | 298 | 0 |
| Italy | 1700 | 6363 | X | X | 15 | 699 | 162 |
| Luxembourg | X | X | X | X | X | 38 | 0 |
| Malta | X | X | X | X | X | X | X |
| Netherlands | 61 | 294 | X | X | 2 | 225 | 0 |
| Norway | 1066 | 7635 | X | X | 79 | 1130 | 60 |
| Poland | 138 | 8588 | X | X | 106 | 8099 | 103 |
| Portugal | 349 | 2627 | X | X | 4 | X | 7 |
| Romania | 410 | 6265 | X | X | X | 5940 | X |
| Spain | 3905 | 6906 | X | X | 92 | 2007 | 40 |
| Sweden | 3442 | 24400 | X | X | 207 | 14301 | 230 |
| Switzerland | 189 | 935 | X | X | 7 | 627 | 7 |
| United Kingdom | 151 | 2027 | X | X | 40 | 1505 | 0 |
| Yugoslavia | 1390 | 9100 | X | X | X | 6300 | 400 |
| **USSR** | **137000** | **791600** | **X** | **X** | **4540** | **791600** | **20000** |
| **OCEANIA** | **71696** | **86595** | | | | | |
| Australia | 65085 | 41658 | X | 0.0 | 62 | X | X |
| Fiji | 350 | 850 | X | 0.0 | 4 | X | X |
| New Zealand | 2300 | 7200 | X | 0.0 | 43 | X | X |
| Papua New Guinea | 3945 | 34447 | 22 | 0.1 | 2 | 0 | 55 |
| Solomon Islands | 16 | 2440 | X | 0.0 | 2 | X | X |
| **ANTARCTICA** | | | | | | | |

**Sources:** U.N. Food and Agriculture Organization; U.N. Economic Commission for Europe; U.N. Environment Program.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 6.2 FOREST PRODUCTS, 1972–83

| | Average Annual Removals (thousand cubic meters) | | | | | | Average Annual Trade in Forest Products (thousand US dollars) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Roundwood | | Fuelwood and Charcoal | | Industrial Wood | | Imports | | Exports | |
| | 1981–83 | Percent Change Over 1972–74 | 1981–83 | Percent Change Over 1972–74 | 1981–83 | Percent Change Over 1972–74 | 1972–74 | 1981–83 | 1972–74 | 1981–83 |
| **WORLD** | **2990590** | **15** | **1604110** | **25** | **1386480** | **5** | **25020252** | **54271302** | **12546694** | **48376687** |
| **AFRICA** | **456909** | **29** | **403950** | **29** | **52952** | **24** | **734271** | **2033054** | **432445** | **1104140** |
| Algeria | 1678 | 24 | 1461 | 24 | 217 | 27 | 101364 | 345655 | 1337 | 0 |
| Angola | 8986 | 19 | 7663 | 22 | 1323 | 9 | 4712 | 504 | 9239 | 98 |
| Benin | 4080 | 31 | 3868 | 30 | 212 | 32 | 143 | 5643 | X | X |
| Botswana | 785 | 10 | 729 | 10 | 56 | 22 | 820 | 1640 | X | X |
| Burkina Faso | 7087 | 22 | 6770 | 26 | 324 | −28 | 826 | 4458 | X | X |
| Burundi | 3434 | 22 | 3395 | 22 | 39 | 26 | 79 | 177 | X | X |
| Cameroon | 10157 | 24 | 7994 | 18 | 2163 | 55 | 4672 | 11478 | 26586 | 108227 |
| Cape Verde | X | X | X | X | X | X | 499 | 902 | X | X |
| Central African Rep | 3061 | 8 | 2544 | 23 | 517 | −31 | 164 | 1790 | 7673 | 26555 |
| Chad | 7946 | 20 | 7479 | 20 | 468 | 21 | 1381 | 1438 | X | X |
| Comoros | X | X | X | X | X | X | X | X | X | X |
| Congo | 2205 | 12 | 1470 | 26 | 735 | −8 | 661 | 1989 | 20433 | 50470 |
| Djibouti | X | X | X | X | X | X | 225 | 38 | X | X |
| Egypt | 1889 | 25 | 1801 | 25 | 88 | 22 | 93113 | 541929 | X | X |
| Equatorial Guinea | 465 | 10 | 415 | 12 | 50 | 0 | X | X | 269 | 3477 |
| Ethiopia | 28989 | 21 | 27630 | 22 | 1692 | 34 | 2216 | 8296 | 4 | X |
| Gabon | 2525 | −25 | 1222 | 8 | 1303 | −42 | 292 | 3969 | 56821 | 145804 |
| Gambia | 789 | 8 | 773 | 7 | 17 | 67 | 100 | 172 | X | X |
| Ghana | 9803 | 26 | 7284 | 28 | 2519 | 20 | 13512 | 2937 | 86385 | 14487 |
| Guinea | 3634 | 21 | 3085 | 22 | 549 | 16 | X | X | 3646 | X |
| Guinea-Bissau | 527 | 11 | 422 | 11 | 105 | 9 | 131 | 98 | 130 | 130 |
| Ivory Coast | 11587 | 15 | 6963 | 39 | 4624 | −9 | 10875 | 18171 | 233936 | 333703 |
| Kenya | 28178 | 44 | 26763 | 42 | 1415 | 81 | 32920 | 23228 | 2403 | 7983 |
| Lesotho | 293 | 18 | 293 | 18 | X | X | X | X | X | X |
| Liberia | 4491 | 25 | 3957 | 30 | 534 | −2 | 1086 | 5553 | 15296 | 45686 |
| Libya | 630 | 24 | 536 | 19 | 94 | 69 | 72765 | 127948 | X | X |
| Madagascar | 6262 | 22 | 5455 | 19 | 807 | 43 | 2770 | 7989 | 704 | 166 |
| Malawi | 6256 | 33 | 5886 | 33 | 371 | 31 | 4104 | 16454 | 220 | 615 |
| Mali | 4457 | 28 | 4175 | 28 | 282 | 24 | 617 | 1174 | X | X |
| Mauritania | 53 | 22 | 7 | 33 | 46 | 21 | X | X | X | X |
| Mauritius | 33 | −10 | 23 | 9 | 10 | −36 | 3850 | 8709 | X | X |
| Morocco | 1606 | 49 | 1105 | 80 | 501 | 8 | 51449 | 154205 | 12826 | 21554 |
| Mozambique | 14199 | 47 | 13350 | 51 | 849 | −2 | 6004 | 12830 | 10560 | 4641 |
| Niger | 3621 | 30 | 3397 | 30 | 224 | 30 | 406 | 285 | X | X |
| Nigeria | 83210 | 38 | 75850 | 33 | 7360 | 125 | 55798 | 223494 | 19149 | 748 |
| Rwanda | 5036 | 7 | 4802 | 3 | 293 | 389 | 232 | 2416 | X | X |
| Senegal | 3784 | 21 | 3277 | 21 | 507 | 28 | 7126 | 24458 | X | X |
| Sierra Leone | 7931 | 27 | 7784 | 27 | 147 | 13 | 1529 | 1130 | X | X |
| Somalia | 4885 | 66 | 4815 | 67 | 70 | 31 | 5237 | 5505 | X | X |
| South Africa | 19003 | 14 | 7000 | 1 | 12003 | 23 | 163526 | 260345 | 82544 | 242807 |
| Sudan | 37067 | 28 | 35417 | 28 | 1650 | 24 | 13408 | 14502 | X | X |
| Swaziland | 2223 | 21 | 560 | 26 | 1663 | 19 | 452 | 1539 | 26033 | 70220 |
| Tanzania, United Rep | 38571 | 31 | 37474 | 32 | 1097 | 7 | 8965 | 16850 | 1445 | 1338 |
| Togo | 724 | 28 | 568 | 28 | 156 | 28 | 356 | 483 | 10 | X |
| Tunisia | 2620 | 24 | 2513 | 24 | 107 | 27 | 31351 | 92035 | 3754 | X |
| Uganda | 25415 | 31 | 23933 | 31 | 1515 | 23 | 3735 | 3501 | 468 | 38 |
| Zaire | 30400 | 26 | 27990 | 28 | 2410 | 9 | 11552 | 5177 | 8621 | 17810 |
| Zambia | 9296 | 31 | 8808 | 30 | 488 | 46 | 12222 | 21877 | 140 | X |
| Zimbabwe | 6900 | 59 | 5546 | 45 | 1354 | 158 | X | 28201 | X | 7649 |
| **NORTH AMERICA** | **612117** | **19** | **149627** | **180** | **462490** | **0** | **4634682** | **10359820** | **7163423** | **16079211** |
| Barbados | X | X | X | X | X | X | 6505 | 24318 | X | X |
| Canada | 141061 | 4 | 5488 | 59 | 135573 | 3 | 386253 | 776067 | 4426255 | 10023162 |
| Costa Rica | 2624 | 0 | 1479 | −3 | 1145 | 6 | 34441 | 73573 | 2897 | 19739 |
| Cuba | 3188 | 27 | 2803 | 32 | 385 | 0 | 61917 | 172618 | X | X |
| Dominican Rep | 566 | 20 | 557 | 26 | 9 | −71 | 23119 | 63071 | 26 | 17 |
| El Salvador | 4446 | 34 | 4334 | 34 | 112 | 42 | 12950 | 33751 | 407 | 2838 |
| Guatemala | 6644 | 23 | 6459 | 31 | 185 | −63 | 15177 | 61934 | 9137 | 17625 |
| Haiti | 5491 | 23 | 5252 | 24 | 239 | 0 | 2007 | 4987 | 114 | X |
| Honduras | 5106 | 23 | 4109 | 37 | 997 | −14 | 19932 | 31228 | 36888 | 33663 |
| Jamaica | 48 | −22 | 13 | 86 | 35 | −36 | 28697 | 95535 | 54 | 2744 |
| Mexico | 19372 | 25 | 12965 | 31 | 6407 | 14 | 109815 | 547233 | 4970 | 10445 |
| Nicaragua | 3291 | 29 | 2411 | 34 | 880 | 17 | 8297 | 13654 | 6964 | 4270 |
| Panama | 2047 | 36 | 1708 | 24 | 339 | 181 | 19517 | 32506 | 884 | 950 |
| Trinidad and Tobago | 83 | −19 | 22 | 12 | 61 | −27 | 20056 | 122331 | 191 | 573 |
| United States | 417891 | 24 | 101922 | 489 | 315969 | −1 | 3866178 | 8263347 | 2669032 | 5961685 |
| **SOUTH AMERICA** | **284316** | **38** | **205156** | **25** | **79161** | **90** | **570651** | **1146548** | **334762** | **1365238** |
| Argentina | 9962 | 2 | 6088 | −2 | 3874 | 10 | 186427 | 255532 | 16102 | 11547 |
| Bolivia | 1348 | 20 | 1116 | 33 | 233 | −18 | 3475 | 12468 | 6121 | 10324 |
| Brazil | 216571 | 43 | 159058 | 25 | 57513 | 138 | 179569 | 196610 | 202240 | 820264 |
| Chile | 13150 | 30 | 5798 | 16 | 7352 | 42 | 8604 | 43300 | 67068 | 333868 |
| Colombia | 16394 | 12 | 13627 | 21 | 2767 | −18 | 40445 | 147481 | 8362 | 51869 |
| Ecuador | 7745 | 40 | 5592 | 49 | 2153 | 21 | 32452 | 82177 | 6295 | 33986 |
| Guyana | 201 | −21 | 12 | 20 | 189 | −23 | 3422 | 6329 | 2067 | 6260 |
| Paraguay | 6786 | 59 | 4374 | 30 | 2412 | 167 | 2771 | 9486 | 14906 | 69102 |
| Peru | 7792 | 22 | 6456 | 27 | 1337 | 2 | 30838 | 63795 | 4057 | 7119 |
| Suriname | 278 | 48 | 22 | 400 | 256 | 40 | 4175 | 12483 | 6133 | 10723 |
| Uruguay | 2556 | 70 | 2305 | 78 | 251 | 22 | 12074 | 22514 | 765 | 6296 |
| Venezuela | 1278 | 16 | 642 | 37 | 636 | 0 | 65754 | 293706 | X | X |

# Table 6.2

| | Average Annual Removals (thousand cubic meters) | | | | | | Average Annual Trade in Forest Products (thousand US dollars) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Roundwood | | Fuelwood and Charcoal | | Industrial Wood | | Imports | | Exports | |
| | 1981–83 | Percent Change Over 1972–74 | 1981–83 | Percent Change Over 1972–74 | 1981–83 | Percent Change Over 1972–74 | 1972–74 | 1981–83 | 1972–74 | 1981–83 |
| **ASIA** | **909430** | **16** | **700308** | **16** | **209123** | **18** | **5397608** | **12721855** | **2709911** | **5728626** |
| Afghanistan | 6539 | 21 | 4991 | 26 | 1549 | 10 | 19238 | 28530 | X | X |
| Bahrain | X | X | X | X | X | X | 4610 | 27376 | 17 | X |
| Bangladesh | 31209 | 27 | 30269 | 28 | 940 | 5 | 8106 | 2132 | 3452 | 5078 |
| Bhutan | 3224 | 19 | 2946 | 19 | 278 | 17 | X | 143 | X | 501 |
| Burma | 18836 | 26 | 15817 | 27 | 3019 | 21 | 6081 | 11207 | 40795 | 120548 |
| China | 227847 | 25 | 154635 | 15 | 73212 | 56 | 272698 | 1419525 | 266715 | 524060 |
| Cyprus | 77 | −12 | 20 | −26 | 57 | −6 | 18656 | 50189 | 122 | 165 |
| India | 228407 | 21 | 208538 | 20 | 19869 | 33 | 61820 | 212042 | 23737 | 26558 |
| Indonesia | 125476 | 5 | 112351 | 18 | 13126 | −46 | 45217 | 196112 | 512776 | 917156 |
| Iran | 6707 | 7 | 2331 | 45 | 4376 | −6 | 73094 | 245828 | 237 | 38 |
| Iraq | 129 | 27 | 79 | 29 | 50 | 25 | 55114 | 142321 | X | X |
| Israel | 118 | 53 | 11 | −15 | 107 | 66 | 103070 | 225992 | 9165 | 13672 |
| Japan | 32536 | −24 | 594 | −61 | 31942 | −22 | 3673023 | 6336158 | 410144 | 802193 |
| Jordan | 10 | −3 | 6 | 42 | 4 | −33 | 8114 | 65965 | 550 | 8855 |
| Kampuchea, Dem | 5118 | 1 | 4551 | −1 | 567 | 14 | 1885 | 1885 | 173 | 173 |
| Korea, Dem People's Rep | 6110 | 19 | 5510 | 22 | 600 | 0 | 1879 | 1879 | X | X |
| Korea, Rep | 10160 | 28 | 6913 | 17 | 3247 | 59 | 336442 | 867897 | 262246 | 346154 |
| Kuwait | X | X | X | X | X | X | 28835 | 157524 | 2121 | 28058 |
| Lao People's Dem Rep | 3832 | 22 | 3605 | 23 | 227 | 3 | 886 | 816 | 1826 | 8706 |
| Lebanon | 221 | −40 | 195 | −44 | 25 | 27 | 34540 | 61873 | 3777 | 3239 |
| Malaysia | 40418 | 185 | 7193 | 26 | 33224 | 293 | 73866 | 215239 | 615444 | 1975786 |
| Mongolia | 2390 | 0 | 1350 | 0 | 1040 | 0 | X | 5913 | 4210 | 9300 |
| Nepal | 14370 | 23 | 13810 | 24 | 560 | 0 | X | X | 5166 | 11667 |
| Oman | X | X | X | X | X | X | X | 60267 | X | X |
| Pakistan | 18574 | 29 | 17980 | 29 | 594 | 25 | 35010 | 82740 | 145 | X |
| Philippines | 35223 | 6 | 27768 | 27 | 7454 | −35 | 38902 | 77664 | 321309 | 385706 |
| Qatar | X | X | X | X | X | X | 2246 | 2505 | X | X |
| Saudi Arabia | X | X | X | X | X | X | 47360 | 676191 | X | X |
| Singapore | X | X | X | X | X | X | 166289 | 514131 | 162183 | 435254 |
| Sri Lanka | 8166 | 19 | 7489 | 17 | 676 | 37 | 9314 | 33182 | 18 | 4269 |
| Syrian Arab Rep | 38 | −12 | 11 | 43 | 27 | −24 | 36254 | 123491 | 512 | 1137 |
| Thailand | 39659 | 17 | 35475 | 24 | 4184 | −22 | 47201 | 253005 | 32513 | 28976 |
| Turkey | 20130 | −45 | 15000 | −50 | 5130 | −21 | 21144 | 70719 | 13323 | 29522 |
| United Arab Emirates | X | X | X | X | X | X | X | X | X | X |
| Viet Nam | 23181 | 23 | 20353 | 22 | 2828 | 31 | 5749 | 8669 | X | X |
| Yemen | X | X | X | X | X | X | X | X | X | X |
| Yemen, Dem | 264 | 26 | 264 | 26 | X | X | 2303 | 11498 | 32 | 29 |
| **EUROPE** | **336348** | **2** | **54569** | **−2** | **281779** | **3** | **13027476** | **26151543** | **9690330** | **20831412** |
| Albania | 2330 | 0 | 1608 | 0 | 722 | 0 | 2106 | 3833 | 773 | 730 |
| Austria | 13767 | 14 | 1413 | 39 | 12354 | 12 | 228254 | 572389 | 637614 | 1379109 |
| Belgium | 2901 | −5 | 471 | 35 | 2430 | −10 | 664606 | 1513544 | 365993 | 877881 |
| Bulgaria | 4862 | 1 | 1729 | 66 | 3134 | −17 | 82988 | 147508 | 11727 | 18147 |
| Czechoslovakia | 19061 | 23 | 1723 | −12 | 17339 | 28 | 80360 | 102285 | 139068 | 400092 |
| Denmark | 2950 | 52 | 367 | 242 | 2583 | 41 | 463313 | 763125 | 75666 | 230411 |
| Finland | 40225 | −4 | 3534 | −48 | 36691 | 5 | 109473 | 281332 | 1891022 | 4488921 |
| France | 38363 | −3 | 10412 | −3 | 27951 | −3 | 1500857 | 2738679 | 628779 | 1253246 |
| German Dem Rep | 10459 | 28 | 734 | 47 | 9725 | 27 | 259150 | 458315 | 59233 | 93367 |
| Germany, Fed Rep | 30610 | −1 | 4133 | 32 | 26476 | −5 | 2219806 | 4997563 | 849341 | 2217544 |
| Greece | 2771 | 8 | 1991 | 1 | 780 | 32 | 139253 | 285423 | 11310 | 41870 |
| Hungary | 6444 | 18 | 2830 | 10 | 3614 | 25 | 239842 | 295205 | 52758 | 85844 |
| Ireland | 835 | 125 | 44 | 264 | 791 | 120 | 145854 | 318896 | 22698 | 37422 |
| Italy | 8836 | 5 | 4216 | 36 | 4620 | −13 | 1334516 | 2945910 | 282792 | 565045 |
| Luxembourg | X | X | X | X | X | X | X | X | X | X |
| Malta | X | X | X | X | X | X | 8116 | 30850 | X | X |
| Netherlands | 906 | −22 | 100 | 224 | 806 | −28 | 943310 | 2067993 | 289502 | 672805 |
| Norway | 9803 | 12 | 788 | 33 | 9015 | 10 | 217663 | 426958 | 493236 | 781237 |
| Poland | 22499 | 11 | 2845 | 44 | 19654 | 7 | 143789 | 210109 | 92917 | 155806 |
| Portugal | 7799 | 9 | 500 | −9 | 7299 | 10 | 61879 | 153869 | 143704 | 380649 |
| Romania | 22124 | 1 | 4349 | −25 | 17775 | 10 | 41751 | 102132 | 218658 | 431885 |
| Spain | 13987 | 9 | 1379 | −68 | 12609 | 49 | 431478 | 650252 | 80140 | 389857 |
| Sweden | 51373 | −12 | 4425 | 69 | 46949 | −16 | 180964 | 540233 | 2759613 | 4831007 |
| Switzerland | 4375 | 6 | 955 | 25 | 3420 | 2 | 308948 | 705867 | 94969 | 333162 |
| United Kingdom | 4151 | 17 | 151 | −57 | 4000 | 25 | 3016297 | 5400479 | 260590 | 654405 |
| Yugoslavia | 14917 | 9 | 3874 | 2 | 11043 | 11 | 183096 | 395994 | 228224 | 510968 |
| **USSR** | **356667** | **−8** | **82500** | **−2** | **274167** | **−9** | **283073** | **971475** | **1417413** | **2554726** |
| **OCEANIA** | **34803** | **23** | **8000** | **25** | **26802** | **23** | **372491** | **887007** | **229665** | **713333** |
| Australia | 16882 | 33 | 2099 | 68 | 14782 | 29 | 326243 | 763200 | 91001 | 236792 |
| Fiji | 224 | 51 | 14 | 45 | 210 | 52 | 4719 | 11179 | 618 | 4300 |
| New Zealand | 10119 | 8 | 50 | −85 | 10069 | 11 | 31640 | 87308 | 113462 | 373830 |
| Papua New Guinea | 6884 | 27 | 5533 | 22 | 1351 | 54 | 1270 | X | 18898 | 75336 |
| Solomon Islands | 512 | 21 | 210 | 18 | 302 | 23 | 190 | 592 | 4647 | 21367 |
| **ANTARCTICA** | | | | | | | | | | |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 6.3 DESERTIFICATION, EARLY 1980s

| | Total Productive Drylands | | Productive Dryland Types: Rangelands | | Rainfed Croplands | | Irrigated Lands | |
|---|---|---|---|---|---|---|---|---|
| | Area (million hectares) | Percent Desertified | Area (million hectares) | Percent Desertified | Area (million hectares) | Percent Desertified | Area (million hectares) | Percent Desertified |
| **Total** | **3257** | **61** | **2556** | **62** | **570** | **60** | **131** | **30** |
| Sudano-Sahelian Africa | 473 | 88 | 380 | 90 | 90 | 80 | 3 | 30 |
| Southern Africa | 304 | 80 | 250 | 80 | 52 | 80 | 2 | 30 |
| Mediterranean Africa | 101 | 83 | 80 | 85 | 20 | 75 | 1 | 40 |
| Western Asia | 142 | 82 | 116 | 85 | 18 | 85 | 8 | 40 |
| Southern Asia | 359 | 70 | 150 | 85 | 150 | 70 | 59 | 35 |
| USSR in Asia | 298 | 55 | 250 | 60 | 40 | 30 | 8 | 25 |
| China and Mongolia | 315 | 69 | 300 | 70 | 5 | 60 | 10 | 30 |
| Australia | 491 | 23 | 450 | 22 | 39 | 30 | 2 | 19 |
| Mediterranean Europe | 76 | 39 | 30 | 30 | 40 | 32 | 6 | 25 |
| South America and Mexico | 293 | 71 | 250 | 72 | 31 | 77 | 12 | 33 |
| North America | 405 | 40 | 300 | 42 | 85 | 39 | 20 | 20 |

**Source:** U.N. Environment Program.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 6.1 Forest Resources, 1980s

**Sources:** Forest extent and reforestation: U.N. Food and Agriculture Organization (FAO), *Forest Resources 1980* (FAO, Rome, 1985). Forest loss, protection, and management: FAO and United Nations Environment Program (UNEP), *Tropical Forest Resources Assessment Project* (FAO, Rome, 1981). FAO and United Nations Economic Commission for Europe (ECE), *The Forest Resources of the ECE Region* (ECE, Geneva, 1985). Reforestation data for China: State Statistical Bureau, *China: A Statistics Survey in 1985*, (New World Press, Beijing, 1985), p. 30.

The U.N. Food and Agriculture Organization (FAO)/United Nations Environment Program (UNEP) study covers only the tropical moist forests in 76 tropical countries and thus should not (but occasionally does) count tropical dry forests or subtropical forests in these countries. The FAO/United Nations Economic Commission for Europe (ECE) report covers all types of forests in the 32 member countries of the ECE.

The forests and open woodland referred to in Table 6.1 are natural stands of woody vegetation in which trees are predominant. For the purpose of this definition, "natural" means all stands except plantations and includes stands that have been degraded to some degree by fire, logging, or agriculture. "Trees" are distinguished from shrubs on the basis of height: a mature tree has a single, well-defined stem and exceeds seven meters in height while a mature shrub is usually less than seven meters high.

Reforestation refers to the establishment of plantations for industrial and non-industrial uses. Plantations are formed in two ways: a. *by afforestation*, forest stands established artificially on land that previously did not carry forest, and b. *by reafforestation*, forest stands established artificially on land that carried forest within the previous 50 years (or within living memory) in which the previous crop has been replaced by a new and essentially different crop. Reforestation does not include regeneration of old crops (either through natural regeneration or forest management), although some countries may have reported this as reforestation. Reforestation figures cannot be subtracted from deforestation figures to derive a "net loss" statistic because the two figures are not comparable.

Data for the FAO/UNEP assessment were collected from research institutes; correspondence with the forestry services of almost all 76 countries; visits to national forestry, land use, and survey institutions in some of the major forestry countries, and to the regional offices of FAO; photographic surveys of all or part of five countries; satellite imagery of all or part of 19 countries; and side-looking airborne radar (SLAR) surveys of four additional countries. Three countries (Burma, India, and Peru) prepared their own national reports. In many cases, data were adjusted by the FAO to fit common definitions and to correspond to a base year of 1980.

The FAO/UNEP statistics were chosen because of their international coverage, relative timeliness, and extensive documentation Even so, the quality of the data varies considerably from country to country. Deforestation estimates were considered reliable by FAO for 33 of the 56 countries for which data collection procedures were documented.

The FAO/ECE survey relied on four types of sources: official data supplied in response to questionnaires; estimates by expert correspondents in certain countries; recent ECE and FAO publications, country reports, and official articles and estimates by the professional staff conducting the study. Most of the data refer to the period around 1980, but no attempt was made to adjust the data to a common baseline year.

For an evaluation and detailed comparison of forest statistics, see Alan Grainger, "Quantifying Changes in Forest Cover in the Humid Tropics: Overcoming Current Limitations," *Journal of World Forest Resource Management*, Vol. 1, pp. 3–23 (1984).

### Table 6.2 Forest Products, 1972–83

**Source:** U.N. Food and Agriculture Organization, *Yearbook of Forest Products 1983* (FAO, Rome, 1985).

Total roundwood refers to all wood in the rough, whether destined for industrial uses or for use as fuelwood.

Fuelwood includes all rough wood used for cooking, heating, and power production. Wood intended for charcoal production, pit kilns, and portable ovens is included.

Industrial roundwood refers to all roundwood products other than fuelwood and charcoal: sawlogs, veneer logs, sleepers, pitprops, pulpwood, and other industrial products.

Imports are usually on a cost, insurance, freight (cif) basis. Exports are usually on a free-on-board (fob) basis. Data for imports and exports are reported in current U.S. dollars.

The FAO compiles forest products data from responses to annual questionnaires sent to national governments. Data from other sources, such as national statistical yearbooks, are also used, and in some cases FAO prepares its own estimates. The FAO revises its data using new information, so the latest figures are subject to revision.

Statistics on the production of fuelwood and charcoal are lacking for many countries. The FAO estimates fuelwood and charcoal production for these countries using population data and country-specific per-capita consumption figures. Consumption of non-coniferous fuelwood ranges from 0.0016 cubic meters per capita per year in Jordan to 0.9783 cubic meters per capita per year in Benin. Consumption estimates were also made for coniferous fuelwood. For both coniferous and non-coniferous fuelwood these per-capita, country-specific consumption estimates were multiplied by the number of people in the country to determine national totals.

### Table 6.3 Extent of Desertification, Early 1980s

**Source:** Mabbutt, J.A., "A New Global Assessment of the Status and Trends of Desertification," *Environmental Conservation*, Vol. 11, No. 2, p. 106 (1984).

Desertification is the diminution or destruction of the biological productivity of the land

and can lead ultimately to desert-like conditions. For this table, the definition was applied only to the world's drylands: hyperarid, arid, semi-arid, and subhumid zones of low and variable rainfall. These regions are inherently vulnerable to water stress and droughts and are particularly vulnerable to deterioration resulting from unsustainable human use of the land.

Desertification is generally associated with a sequence of interactive processes: impoverishment of, and reduction in, vegetative cover; exposure of the soil surface to accelerated wind and water erosion; reduction of the soil's organic matter and nutrient content; and deterioration of the structure, moisture-holding capacity, and fertility of the soil.

The principal indicators used to assess desertification include deterioration of rangeland; deterioration of rainfed croplands, waterlogging and salinization of irrigated lands; deforestation and destruction of woody vegetation; decline in the availability and quality of surface and ground water, and encroachment and growth of sand sheets and dunes.

Generally, moderate desertification implies a loss of productivity of less than 25 percent; severe desertification causes a loss of productivity of 25 to 50 percent, and very severe desertification causes a loss of productivity of over 50 percent. The "percent desertified" used in this table is the fraction of the productive land type that is moderately to very severely desertified.

Data for this table were compiled from many sources and involve extrapolation from partial data. More than 100 countries affected by desertification received desertification questionnaires from UNEP, that requested information on land-use patterns, the status and trends of desertification, and actions taken to combat desertification. Twenty-five countries submitted extensive reports updating earlier studies conducted for the U.N. Conference on Desertification (1977). Regional assessments were prepared by U.N. regional commissions (including the U.N. Sudano-Sahelian office). Other published and unpublished works by the United Nations Educational, Scientific, and Cultural Organization, the World Meteorological Organization, FAO, UNEP, and others were used. Refer to these sources for further details on data and methods.

# 7. Wildlife Resources

Many national governments and other organizations have only recently begun to monitor their valuable wildlife resources (species and ecosystems) and to collect and publish the statistics needed to assess them. This edition of *World Resources* presents tables on a few national and international efforts to protect natural ecosystems, as well as data on the number of mammals threatened with extinction.

Information on protected areas, as defined by the International Union for Conservation of Nature and Natural Resources (IUCN), is shown in Table 7.1. Five categories of protected areas are included: strict nature reserves, national parks, natural monuments, wildlife sanctuaries, and protected landscapes. A few well-known examples are the Amboseli and Serengeti National Parks of Kenya and Tanzania; the Wolung Nature Reserve in China; the protected landscape of the Lake District in England; and the Great Barrier Reef Marine Park in Australia.

Not included are many local and provincial areas, areas less than 1,000 hectares in size, areas privately owned, and areas where local customs permit hunting and other consumptive uses of wildlife. The total protected area for each country is therefore greater than indicated in the tables.

However, areas that are officially designated "protected" by national authorities may not be well-protected or adequately managed in practice. Management and enforcement practices vary widely within and among countries, and many protected areas are being encroached upon by settlements and degraded by industrial pollution. Furthermore, because there is no widely accepted classification of ecological areas (terrestrial and aquatic), experts and authorities have considerable difficulty making an effective case for additional protected areas when faced with immediate demands for more land for agriculture and settlements.

Antarctica is a special case. Seven reserves have been established under the auspices of the Antarctica Treaty of 1959. However, because even tourism and scientific research can disrupt this fragile natural system, new areas are being considered for protection by the Scientific Committee for Antarctic Research and the IUCN.

Table 7.2 presents data on protected areas that are of global importance. They include Biosphere Reserves, World Heritage Sites, and Wetlands of International Significance.

Biosphere Reserves are terrestrial and coastal environments that have been internationally recognized for conservation, study, and sustained development. A major goal of the Man and the Biosphere Program of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is to build a network of representative samples of the world's 194 biogeographical provinces. As of December 1985, 243 Biosphere Reserves had been established in 65 countries, covering about 100 (52 percent) of these provinces. These reserves include Mapimi Reserve in Mexico, Everglades National Park in the United States, Cévennes National Park in France, Sakaerat Reserve in Thailand, Changbai Reserve in China, Berezinsky Zapovednik in the Soviet Union, and the Tai Forest in the Ivory Coast.

Table 7.3 presents data on globally threatened mammals of Africa, the Americas, and Australia. (Comparable data from IUCN for Europe and Asia are not available, nor are global data on other vertebrates, invertebrates, and plants.) Numbers of species threatened at the national level are available for the Americas and for OECD countries. See Part II, Chapter 6, "Wildlife and Habitat," (Tables 6.3 and 6.4). The total number of mammal species that are threatened globally include those listed as endangered, vulnerable, rare, indeterminate, and insufficiently known. The table does not include species (or subspecies) that are threatened within one country but are relatively abundant in other countries. For example, the ring-tail cat *(Bassariscus sumichrasti)*, a member of the raccoon family, is now considered threatened in Costa Rica, however, since substantial populations are found in other countries of Central America, it is not included on this list.

Brazil has the largest number of species that are globally threatened. Examples of threatened mammals include the bridled nailtail wallaby (*Onychogalea fraenata*), in Australia; the gorilla (*Gorilla gorilla*), in equatorial Africa; the giant anteater (*Myrmecophaga tridactyla*), in Central and South America; and the polar bear (*Ursus maritimus*) in North America. A few threatened species, such as the polar bear, the vicuña (*Vicugna vicugna*), and the Argentine Pampas Deer (*Ozotoceros bezoarticus celer*), are responding to conservation efforts, and their populations are growing. Others, such as the Golden Lion Tamarin (*Leontopithecus rosalia*), have declining populations and it is expected that, unless individuals bred in captivity can be successfully reintroduced to the wild, this species will become extinct.

# Table 7.1 MAJOR PROTECTED AREAS, 1985

| | Protected Areas 1985 Number | Protected Areas 1985 Total Size (thousand hectares) | Percentage of Territory Protected 1985 | Protected Area per Thousand Population 1985 (hectares) |
|---|---|---|---|---|
| **WORLD** | **3513** | **423774** | **3.2** | **88** |
| **AFRICA** | **443** | **88662** | **3.0** | **160** |
| Algeria | 5 | 227 | 0.1 | 10 |
| Angola | 5 | 1518 | 1.2 | 173 |
| Benin | 2 | 844 | 7.6 | 211 |
| Botswana | 8 | 11644 | 19.9 | 10791 |
| Burkina Faso | 6 | 683 | 2.5 | 98 |
| Burundi | 0 | 0 | 0.0 | 0 |
| Cameroon | 15 | 2228 | 4.7 | 229 |
| Cape Verde | 0 | 0 | 0.0 | 0 |
| Central African Rep | 7 | 3904 | 6.3 | 1521 |
| Chad | 1 | 114 | 0.1 | 23 |
| Comoros | 0 | 0 | 0.0 | 0 |
| Congo | 10 | 1353 | 4.0 | 778 |
| Djibouti | 0 | 0 | 0.0 | 0 |
| Egypt | 1 | 17 | 0.0 | 0 |
| Equatorial Guinea | 0 | 0 | 0.0 | 0 |
| Ethiopia | 10 | 3028 | 2.7 | 83 |
| Gabon | 5 | 1673 | 6.5 | 1435 |
| Gambia | 0 | 0 | 0.0 | 0 |
| Ghana | 8 | 1175 | 5.1 | 87 |
| Guinea | 1 | 13 | 0.1 | 2 |
| Guinea-Bissau | 0 | 0 | 0.0 | 0 |
| Ivory Coast | 10 | 1865 | 5.9 | 190 |
| Kenya | 28 | 3105 | 5.5 | 151 |
| Lesotho | 1 | 7 | 0.2 | 4 |
| Liberia | 1 | 131 | 1.4 | 60 |
| Libya | 2 | 130 | 0.1 | 36 |
| Madagascar | 14 | 675 | 1.2 | 67 |
| Malawi | 9 | 1081 | 11.5 | 154 |
| Mali | 6 | 876 | 0.7 | 109 |
| Mauritania | 2 | 1483 | 1.4 | 785 |
| Mauritius | 3 | 4 | 2.2 | 4 |
| Morocco | 2 | 41 | 0.1 | 2 |
| Mozambique | 6 | 1815 | 2.3 | 129 |
| Niger | 3 | 372 | 0.3 | 61 |
| Nigeria | 3 | 868 | 1.0 | 9 |
| Rwanda | 2 | 262 | 10.5 | 43 |
| Senegal | 9 | 2177 | 11.3 | 334 |
| Sierra Leone | 1 | 98 | 1.4 | 27 |
| Somalia | 1 | 334 | 0.5 | 60 |
| South Africa | 149 | 5689 | 4.7 | 176 |
| Sudan | 3 | 1916 | 0.8 | 89 |
| Swaziland | 4 | 40 | 2.3 | 62 |
| Tanzania, United Rep | 15 | 10602 | 12.0 | 471 |
| Togo | 7 | 473 | 8.7 | 162 |
| Tunisia | 3 | 33 | 0.2 | 5 |
| Uganda | 18 | 1332 | 6.7 | 85 |
| Zaire | 9 | 8827 | 3.9 | 267 |
| Zambia | 19 | 6664 | 9.0 | 1000 |
| Zimbabwe | 17 | 2758 | 7.1 | 315 |
| **NORTH AMERICA** | **422** | **161860** | **6.9** | **404** |
| Barbados | 0 | 0 | 0.0 | 0 |
| Canada | 78 | 22949 | 2.5 | 896 |
| Costa Rica | 21 | 412 | 8.1 | 159 |
| Cuba | 4 | 24 | 0.2 | 2 |
| Dominican Rep | 5 | 220 | 4.5 | 35 |
| El Salvador | 0 | 0 | 0.0 | 0 |
| Guatemala | 2 | 60 | 0.5 | 7 |
| Haiti | 2 | 5 | 0.2 | 1 |
| Honduras | 4 | 423 | 3.8 | 97 |
| Jamaica | 0 | 0 | 0.0 | 0 |
| Mexico | 29 | 938 | 0.5 | 12 |
| Nicaragua | 2 | 17 | 0.1 | 5 |
| Panama | 6 | 661 | 8.7 | 303 |
| Trinidad and Tobago | 8 | 17 | 3.2 | 15 |
| United States | 251 | 64946 | 7.1 | 273 |
| **SOUTH AMERICA** | **267** | **50060** | **2.9** | **186** |
| Argentina | 29 | 2594 | 0.9 | 85 |
| Bolivia | 12 | 4708 | 4.3 | 739 |
| Brazil | 50 | 11894 | 1.4 | 88 |
| Chile | 64 | 12737 | 17.0 | 1055 |
| Colombia | 30 | 3959 | 3.8 | 138 |
| Ecuador | 12 | 2627 | 9.5 | 280 |
| Guyana | 1 | 12 | 0.1 | 12 |
| Paraguay | 9 | 1121 | 2.8 | 304 |
| Peru | 11 | 2408 | 1.9 | 122 |
| Suriname | 9 | 582 | 3.6 | 1650 |
| Uruguay | 6 | 29 | 0.2 | 10 |
| Venezuela | 34 | 7389 | 8.4 | 402 |

# Table 7.1

| | Protected Areas 1985 Number | Total Size (thousand hectares) | Percentage of Territory Protected 1985 | Protected Area per Thousand Population 1985 (hectares) |
|---|---|---|---|---|
| **ASIA** | **790** | **52414** | **2.0** | **19** |
| Afghanistan | 0 | 0 | 0.0 | 0 |
| Bahrain | 0 | 0 | 0.0 | 0 |
| Bangladesh | 3 | 32 | 0.2 | 0 |
| Bhutan | 11 | 950 | 20.2 | 670 |
| Burma | 0 | 0 | 0.0 | 0 |
| China | 63 | 2306 | 0.2 | 2 |
| Cyprus | 0 | 0 | 0.0 | 0 |
| India | 239 | 11149 | 3.7 | 15 |
| Indonesia | 140 | 13755 | 7.6 | 83 |
| Iran | 24 | 3056 | 1.9 | 68 |
| Iraq | 0 | 0 | 0.0 | 0 |
| Israel | 5 | 34 | 1.7 | 8 |
| Japan | 50 | 2196 | 5.9 | 18 |
| Jordan | 2 | 34 | 0.4 | 10 |
| Kampuchea, Dem | 1 | 11 | 0.1 | 1 |
| Korea, Dem People's Rep | 0 | 0 | 0.0 | 0 |
| Korea, Rep | 14 | 476 | 4.8 | 12 |
| Kuwait | 0 | 0 | 0.0 | 0 |
| Lao People's Dem Rep | 0 | 0 | 0.0 | 0 |
| Lebanon | 0 | 0 | 0.0 | 0 |
| Malaysia | 34 | 1559 | 4.7 | 100 |
| Mongolia | 4 | 4673 | 3.0 | 2459 |
| Nepal | 10 | 974 | 7.1 | 59 |
| Oman | 1 | 20 | 0.1 | 16 |
| Pakistan | 52 | 6537 | 8.4 | 64 |
| Philippines | 26 | 391 | 1.3 | 7 |
| Qatar | 0 | 0 | 0.0 | 0 |
| Saudi Arabia | 1 | 450 | 0.2 | 40 |
| Singapore | 1 | 2 | 4.3 | 1 |
| Sri Lanka | 37 | 643 | 9.9 | 39 |
| Syrian Arab Rep | 0 | 0 | 0.0 | 0 |
| Thailand | 45 | 2721 | 5.3 | 53 |
| Turkey | 15 | 287 | 0.4 | 6 |
| United Arab Emirates | 0 | 0 | 0.0 | 0 |
| Viet Nam | 12 | 158 | 0.5 | 3 |
| Yemen | 0 | 0 | 0.0 | 0 |
| Yemen, Dem | 0 | 0 | 0.0 | 0 |
| **EUROPE** | **704** | **17239** | **3.6** | **35** |
| Albania | 4 | 10 | 0.4 | 3 |
| Austria | 27 | 297 | 3.6 | 40 |
| Belgium | 4 | 12 | 0.4 | 1 |
| Bulgaria | 12 | 56 | 0.5 | 6 |
| Czechoslovakia | 28 | 1157 | 9.2 | 74 |
| Denmark | 23 | 126 | 3.0 | 24 |
| Finland | 33 | 803 | 2.6 | 165 |
| France | 37 | 1655 | 3.0 | 30 |
| German Dem Rep | 13 | 21 | 0.2 | 1 |
| Germany, Fed Rep | 45 | 531 | 2.2 | 9 |
| Greece | 14 | 63 | 0.5 | 6 |
| Hungary | 36 | 421 | 4.6 | 39 |
| Ireland | 3 | 20 | 0.2 | 6 |
| Italy | 34 | 517 | 1.8 | 9 |
| Luxembourg | 4 | 114 | 38.1 | 315 |
| Malta | 0 | 0 | 0.0 | 0 |
| Netherlands | 50 | 164 | 4.8 | 11 |
| Norway | 61 | 4717 | 12.2 | 1137 |
| Poland | 15 | 113 | 0.4 | 3 |
| Portugal | 12 | 381 | 4.2 | 38 |
| Romania | 9 | 98 | 0.4 | 4 |
| Spain | 56 | 1701 | 3.4 | 44 |
| Sweden | 67 | 1463 | 3.6 | 177 |
| Switzerland | 19 | 121 | 3.0 | 19 |
| United Kingdom | 57 | 1553 | 6.4 | 28 |
| Yugoslavia | 20 | 336 | 1.3 | 14 |
| **USSR** | **141** | **15111** | **0.7** | **54** |
| **OCEANIA** | **739** | **38232** | **4.5** | **1540** |
| Australia | 581 | 35414 | 4.6 | 2254 |
| Fiji | 2 | 5 | 0.3 | 8 |
| New Zealand | 147 | 2787 | 10.4 | 847 |
| Papua New Guinea | 2 | 3 | 0.0 | 1 |
| Solomon Islands | 0 | 0 | 0.0 | 0 |
| **ANTARCTICA** | **7** | **195** | **0.0** | **NA** |

**Source:** International Union for Conservation of Nature and Natural Resources.
0 = zero or less than one-half the unit of measure; NA = not applicable.
For additional information, see Sources and Technical Notes.

# Table 7.2 BIOSPHERE RESERVES, WORLD HERITAGE SITES,

| | Biosphere Reserves 1985 | | Natural World Heritage Sites 1985 | Wetlands of International Importance 1985 | |
|---|---|---|---|---|---|
| | Number | Area (hectares) | Number | Number | Area (hectares) |
| **WORLD** | **243** | **154919316** | **63** | **329** | **19304999** |
| **AFRICA** | **36** | **11761499** | **20** | **13** | **1310548** |
| Algeria | 0 | 0 | 1 | 2 | 8400 |
| Angola | 0 | 0 | — | — | — |
| Benin | 0 | 0 | 0 | — | — |
| Botswana | 0 | 0 | — | — | — |
| Burkina Faso | 0 | 0 | — | — | — |
| Burundi | 0 | 0 | 0 | — | — |
| Cameroon | 3 | 850000 | 0 | — | — |
| Cape Verde | 0 | 0 | — | — | — |
| Central African Rep | 2 | 1640200 | 0 | — | — |
| Chad | 0 | 0 | — | — | — |
| Comoros | 0 | 0 | — | — | — |
| Congo | 1 | 110000 | — | — | — |
| Djibouti | 0 | 0 | — | — | — |
| Egypt | 1 | 1000 | 0 | — | — |
| Equatorial Guinea | 0 | 0 | — | — | — |
| Ethiopia | 0 | 0 | 1 | — | — |
| Gabon | 1 | 15000 | — | — | — |
| Gambia | 0 | 0 | — | — | — |
| Ghana | 1 | 7770 | 0 | — | — |
| Guinea | 2 | 133300 | 1 | — | — |
| Guinea-Bissau | 0 | 0 | — | — | — |
| Ivory Coast | 2 | 1480000 | 3 | — | — |
| Kenya | 4 | 851359 | — | — | — |
| Lesotho | 0 | 0 | — | — | — |
| Liberia | 0 | 0 | — | — | — |
| Libya | 0 | 0 | 0 | — | — |
| Madagascar | 0 | 0 | 0 | — | — |
| Malawi | 0 | 0 | 1 | — | — |
| Mali | 1 | 771000 | 0 | — | — |
| Mauritania | 0 | 0 | 0 | 1 | 1173000 |
| Mauritius | 1 | 3594 | — | — | — |
| Morocco | 0 | 0 | 0 | 4 | 10580 |
| Mozambique | 0 | 0 | 0 | — | — |
| Niger | 0 | 0 | 0 | — | — |
| Nigeria | 1 | 460 | 0 | — | — |
| Rwanda | 1 | 15065 | — | — | — |
| Senegal | 3 | 1093756 | 2 | 3 | 96000 |
| Sierra Leone | 0 | 0 | — | — | — |
| Somalia | 0 | 0 | — | — | — |
| South Africa | 0 | 0 | — | 2 | 9968 |
| Sudan | 2 | 1900970 | 0 | — | — |
| Swaziland | 0 | 0 | — | — | — |
| Tanzania, United Rep | 2 | 2337900 | 3 | — | — |
| Togo | 0 | 0 | — | — | — |
| Tunisia | 4 | 32425 | 1 | 1 | 12600 |
| Uganda | 1 | 220000 | — | — | — |
| Zaire | 3 | 297700 | 4 | — | — |
| Zambia | 0 | 0 | 0 | — | — |
| Zimbabwe | 0 | 0 | 1 | — | — |
| **NORTH AMERICA** | **50** | **12927433** | **19** | **17** | **10380014** |
| Barbados | 0 | 0 | — | — | — |
| Canada | 2 | 58147 | 5 | 17 | 10380014 |
| Costa Rica | 1 | 500000 | 1 | — | — |
| Cuba | 1 | 10000 | 0 | — | — |
| Dominican Rep | 0 | 0 | 0 | — | — |
| El Salvador | 0 | 0 | — | — | — |
| Guatemala | 0 | 0 | 1 | — | — |
| Haiti | 0 | 0 | 0 | — | — |
| Honduras | 1 | 500000 | 1 | — | — |
| Jamaica | 0 | 0 | 0 | — | — |
| Mexico | 3 | 473200 | 0 | — | — |
| Nicaragua | 0 | 0 | 0 | — | — |
| Panama | 1 | 575000 | 1 | — | — |
| Trinidad and Tobago | 0 | 0 | — | — | — |
| United States | 41 | 10811086 | 10 | — | — |
| **SOUTH AMERICA** | **20** | **10856377** | **6** | **3** | **14877** |
| Argentina | 3 | 1993280 | 2 | — | — |
| Bolivia | 2 | 300000 | 0 | — | — |
| Brazil | 0 | 0 | 0 | — | — |
| Chile | 7 | 2575469 | 0 | 1 | 4877 |
| Colombia | 3 | 2514375 | 0 | — | — |
| Ecuador | 1 | 766514 | 2 | — | — |
| Guyana | 0 | 0 | 0 | — | — |
| Paraguay | 0 | 0 | — | — | — |
| Peru | 3 | 2506739 | 2 | — | — |
| Suriname | 0 | 0 | — | 1 | 10000 |
| Uruguay | 1 | 200000 | — | 1 | X |
| Venezuela | 0 | 0 | — | — | — |

# AND WETLANDS OF INTERNATIONAL IMPORTANCE, 1985

| | Biosphere Reserves 1985 | | World Heritage Sites 1985 | Wetlands of International Importance 1985 | |
|---|---|---|---|---|---|
| | Number | Area (hectares) | Number | Number of Sites | Area (hectares) |
| **ASIA** | **30** | **4598638** | **6** | **32** | **1450883** |
| Afghanistan | 0 | 0 | 0 | — | — |
| Bahrain | 0 | 0 | — | — | — |
| Bangladesh | 0 | 0 | 0 | — | — |
| Bhutan | 0 | 0 | — | — | — |
| Burma | 0 | 0 | — | — | — |
| China | 3 | 425645 | — | — | — |
| Cyprus | 0 | 0 | 0 | — | — |
| India | 0 | 0 | 3 | 2 | 119400 |
| Indonesia | 6 | 1319440 | — | — | — |
| Iran | 9 | 2609731 | 0 | 18 | 1297550 |
| Iraq | 0 | 0 | 0 | — | — |
| Israel | 0 | 0 | — | — | — |
| Japan | 4 | 116000 | — | 2 | 5571 |
| Jordan | 0 | 0 | 0 | 1 | 7372 |
| Kampuchea, Dem | 0 | 0 | — | — | — |
| Korea, Dem People's Rep | 0 | 0 | — | — | — |
| Korea, Rep | 1 | 37430 | — | — | — |
| Kuwait | 0 | 0 | — | — | — |
| Lao People's Dem Rep | 0 | 0 | — | — | — |
| Lebanon | 0 | 0 | 0 | — | — |
| Malaysia | 0 | 0 | — | — | — |
| Mongolia | 0 | 0 | — | — | — |
| Nepal | 0 | 0 | 2 | — | — |
| Oman | 0 | 0 | 0 | — | — |
| Pakistan | 1 | 31355 | 0 | 9 | 20990 |
| Philippines | 1 | 23525 | 0 | — | — |
| Qatar | 0 | 0 | 0 | — | — |
| Saudi Arabia | 0 | 0 | 0 | — | — |
| Singapore | 0 | 0 | — | — | — |
| Sri Lanka | 2 | 9412 | 0 | — | — |
| Syrian Arab Rep | 0 | 0 | 0 | — | — |
| Thailand | 3 | 26100 | — | — | — |
| Turkey | 0 | 0 | 1 | — | — |
| United Arab Emirates | 0 | 0 | — | — | — |
| Viet Nam | 0 | 0 | — | — | — |
| Yemen | 0 | 0 | 0 | — | — |
| Yemen, Dem | 0 | 0 | 0 | — | — |
| **EUROPE** | **78** | **73213585** | **7** | **224** | **1977797** |
| Albania | 0 | 0 | — | — | — |
| Austria | 4 | 27600 | — | 5 | X |
| Belgium | 0 | 0 | — | — | — |
| Bulgaria | 17 | 17411 | 2 | 4 | 3240 |
| Czechoslovakia | 3 | 168892 | — | — | — |
| Denmark | 1 | 70000000 | 0 | 26 | 593372 |
| Finland | 0 | 0 | — | 11 | 101343 |
| France | 4 | 344527 | 1 | — | — |
| German Dem Rep | 2 | 3497 | — | 8 | 49600 |
| Germany, Fed Rep | 1 | 13100 | 0 | 20 | 314315 |
| Greece | 2 | 8840 | 0 | 11 | 78200 |
| Hungary | 5 | 128883 | 0 | 8 | 29450 |
| Ireland | 2 | 8808 | — | 1 | 110 |
| Italy | 3 | 33738 | 0 | 40 | 37292 |
| Luxembourg | 0 | 0 | 0 | — | — |
| Malta | 0 | 0 | 0 | — | — |
| Netherlands | 0 | 0 | — | 13 | 263185 |
| Norway | 1 | 1555000 | 0 | 14 | 17545 |
| Poland | 4 | 25576 | 1 | 5 | 7090 |
| Portugal | 1 | 395 | 0 | 2 | 30563 |
| Romania | 3 | 41213 | — | — | — |
| Spain | 9 | 424977 | 0 | 3 | 52392 |
| Sweden | 0 | 0 | 0 | 20 | 271075 |
| Switzerland | 1 | 16870 | 0 | 2 | 1816 |
| United Kingdom | 13 | 44258 | 0 | 28 | 89115 |
| Yugoslavia | 2 | 350000 | 3 | 2 | 18094 |
| **USSR** | **17** | **36838654** | **0** | **12** | **2880100** |
| **OCEANIA** | **12** | **4723130** | **5** | **28** | **1290780** |
| Australia | 12 | 4723130 | 5 | 26 | 1275973 |
| Fiji | 0 | 0 | — | — | — |
| New Zealand | 0 | 0 | 0 | 2 | 14807 |
| Papua New Guinea | 0 | 0 | — | — | — |
| Solomon Islands | 0 | 0 | — | — | — |
| **ANTARCTICA** | | | | | |

**Sources:** International Union for Conservation of Nature and Natural Resources; Man and the Biosphere Program of UNESCO.
0 = zero; X = not available; — = country not a full party to the Convention.
For additional information, see Sources and Technical Notes.

# Table 7.3 MAMMALS OF AFRICA, THE AMERICAS, AND AUSTRALIA, 1985

| | Total Number of Species | Number of Species Globally Threatened |
|---|---|---|
| **AFRICA** | | |
| Algeria | 97 | 11 |
| Angola | 275 | 12 |
| Benin | 187 | 7 |
| Botswana | 154 | 7 |
| Burkina Faso | 147 | 6 |
| Burundi | 103 | 6 |
| Cameroon | 297 | 16 |
| Cape Verde | 9 | 3 |
| Central African Rep | 208 | 7 |
| Chad | 131 | 11 |
| Congo | 198 | 11 |
| Djibouti | 22 | 6 |
| Egypt | 105 | 10 |
| Equatorial Guinea | 182 | 12 |
| Ethiopia | 256 | 16 |
| Gabon | 190 | 9 |
| Gambia | 108 | 4 |
| Ghana | 222 | 9 |
| Guinea | 188 | 10 |
| Guinea Bissau | 109 | 6 |
| Ivory Coast | 226 | 12 |
| Kenya | 308 | 9 |
| Lesotho | 33 | 2 |
| Liberia | 193 | 11 |
| Libya | 76 | 9 |
| Malawi | 192 | 5 |
| Mali | 136 | 10 |
| Mauritania | 61 | 10 |
| Morocco | 108 | 8 |
| Mozambique | 183 | 6 |
| Namibia | 161 | 10 |
| Niger | 131 | 9 |
| Nigeria | 274 | 18 |
| Rwanda | 147 | 7 |
| Sao Tome | 7 | 0 |
| Senegal | 166 | 10 |
| Sierra Leone | 178 | 10 |
| Somalia | 173 | 14 |
| South Africa | 279 | 16 |
| Sudan | 266 | 16 |
| Swaziland | 46 | 3 |
| Tanzania | 310 | 12 |
| Togo | 196 | 6 |
| Tunisia | 77 | 8 |
| Uganda | 311 | 10 |
| Western Sahara | 15 | 7 |
| Zaire | 409 | 17 |
| Zambia | 228 | 6 |
| Zimbabwe | 194 | 7 |
| **NORTH AMERICA** | | |
| Canada | 163 | 8 |
| Greenland (Denmark) | 26 | 7 |
| United States | 367 | 25 |
| **CENTRAL AMERICA** | | |
| Belize | 124 | 9 |
| Costa Rica | 200 | 10 |
| El Salvador | 135 | 7 |
| Guatemala | 179 | 9 |
| Honduras | 173 | 8 |
| Mexico | 440 | 15 |
| Nicaragua | 175 | 9 |
| Panama | 211 | 12 |
| **SOUTH AMERICA** | | |
| Argentina | 272 | 25 |
| Bolivia | 275 | 24 |
| Brazil | 413 | 38 |
| Chile | 112 | 10 |
| Colombia | 330 | 23 |
| Ecuador | 280 | 20 |
| French Guiana | 152 | 11 |
| Guyana | 193 | 12 |
| Paraguay | 154 | 14 |
| Peru | 350 | 30 |
| Suriname | 188 | 11 |
| Uruguay | 82 | 7 |
| Venezuela | 293 | 18 |
| **AUSTRALIA** | **299** | **46** |

**Source:** International Union for Conservation of Nature and Natural Resources.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 7.1 Major Protected Areas, 1985

**Sources:** International Union for Conservation of Nature and Natural Resources (IUCN), Commission on National Parks and Protected Areas, *1985 United Nations List of National Parks and Protected Areas*, (IUCN, Gland, Switzerland and Cambridge, England, 1985), and unpublished data supplied by the Conservation Monitoring Center, (IUCN, Cambridge, United Kingdom, August 1985.)

The Protected Areas Data Unit of the IUCN Conservation Monitoring Center works with the Commission on National Parks and Protected Areas (one of six commissions of the International Union for Conservation of Nature and Natural Resources) to maintain a detailed listing of protected areas in all countries. Five of the ten categories of protected areas recognized by IUCN are included in the table. They are:

■ *Category I. Scientific reserves and strict nature reserves.* These areas possess outstanding and representative ecosystems. The sites are generally closed to public access. Their size is determined by the area required to ensure the integrity of the site. In many of these sites, natural perturbations (e.g., insect epidemics, forest fires) are allowed to occur.

■ *Category II. National parks and provincial parks.* These are relatively large areas of national or international significance that are not materially altered by humans. Access is controlled, but visitors are encouraged to use the areas for recreation and study.

■ *Category III. Natural monuments and natural landmarks.* These areas contain unique geological formations, special animals or plants, or unusual habitat. Areas vary in size. Access is usually restricted.

■ *Category IV. Managed nature reserves and wildlife sanctuaries.* These sites are designated mainly to provide protection for particular uses such as conservation of a nationally significant plant or animal species. Some areas may require management. For example, a particular grassland or heath community may be protected and perpetuated best by allowing livestock grazing. The sizes of the areas vary. Public access is restricted to scientific and educational purposes.

■ *Category V. Protected landscapes and seascapes.* Areas so designated may be entirely natural, without any human artifacts, or may include cultural landscapes. Protected landscapes may be coastlines, lake shores, hilly or mountainous terrain along scenic highways, etc. Areas vary in size, and public control depends on the use of the area.

Each area is greater than 1,000 hectares in size. Islands less than 1,000 hectares but greater than 100 hectares are also included.

Data for Categories VI, VII, and VIII are less complete and therefore omitted. Resources Reserves (Category VI) are relatively isolated, uninhabited areas that have been little studied. Anthropological Reserves (Category VII) are natural areas in which humans are an integral component. Management is oriented toward the maintenance of habitat for traditional societies. Multiple Use Management Areas (Category VIII) are large areas in which the principal goal is to manage renewable resources such as timber, game, and recreation potential on a sustained basis. Biosphere Reserves (Category IX) and World Heritage Sites—natural areas—(Category X) are shown in Table 7.2.

Continental and world totals include information for countries not included in the table because they have a population of less than 240,000. The Bahamas, for example, have four protected areas totalling 122,540 hectares, and Iceland has 21 protected areas totalling 789,420 hectares. Data for the Soviet Union include protected areas in the Ukraine and Byelorussia. Data for China include Taiwan. Greenland data are included in the subtotal for North America; they are excluded from Denmark.

### Table 7.2 Biosphere Reserves, World Heritage Sites, and Wetlands of International Importance, 1985

**Sources:** Biosphere Reserves and World Heritage Sites: Man and the Biosphere Program, UNESCO *List of Biosphere Reserves* (UNESCO, Paris, December 1984); World Heritage Secretariat UNESCO, "Properties Inscribed on the World Heritage List by Decision of the World Heritage Committee," (UNESCO, Paris, December 1985); International Union for Conservation of Nature and Natural Resources (IUCN), Commission on National Parks and Protected Areas, *The 1985 United Nations List of National Parks and Protected Areas* (IUCN, Gland, Switzerland, 1985); and Conservation Monitoring Center, IUCN (IUCN, unpublished data, Cambridge, England, August 1985). Wetlands of International Importance: Conservation Monitoring Center, IUCN (IUCN, unpublished list, Cambridge, England, August 1985).

Biosphere Reserves are an international network of protected areas approved by the International Coordinating Council of UNESCO's Man and the Biosphere (MAB) Program. Each area must contain an ecosystem that is typical of a biogeographical province in terms of diversity, naturalness, and effectiveness as a conservation unit. Each Biosphere Reserve must include a minimally disturbed, defined core area available for conservation and research. Around the core area there must be a transition area, which may contain geographically defined areas for specific activities such as experimental research on the functioning of ecosystems, rehabilitation of modified or degraded ecosystems, or traditional uses.

World Heritage Sites are structures or natural areas of "outstanding universal value." (Only natural sites are included in the table.) Sites are nominated by any of the countries party to the World Heritage Convention and are reviewed for the convention committee by IUCN. To be accepted, a natural site must contain an example of a major stage of the earth's evolutionary history; a significant ongoing geological process; a unique or superlative natural phenomenon, formation or feature; or a habitat for endangered or rare species of plants and animals required for the survival of the species.

Areas that are designated Biosphere Reserves, World Heritage Sites, or Wetlands of International Importance, and are also national parks, natural monuments, etc. are listed under both headings.

In the category of Biosphere Reserves, Greenland is included under Denmark and Ukraine and Byelorussia are included in the USSR figure. The United States and Canada share one World Heritage Site (Kluane-Wrangell/St. Elias National Park), which is listed for both countries.

Wetlands of International Importance are specific wetlands so designated by any of the 38 countries that have ratified the Convention on Wetlands of International Importance Especially as Waterfowl Habitat. The collection of wetland data is carried out by IUCN with the assistance of the International Waterfowl Research Bureau (IWRB), the International Council for Bird Preservation (ICBP), and the United Nations Environment Program (UNEP). The data are maintained by the Conservation Monitoring Center at Cambridge, England.

In the category of Wetlands of International Importance, the Netherlands includes the Netherlands Antilles. Iceland, which has one Wetland of International Importance (20,000 hectares), is included in the European and world totals.

### Table 7.3 Mammals of Africa, the Americas, and Australia, 1985

**Sources:** International Union for Conservation of Nature and Natural Resources (IUCN), *The IUCN Mammal Red Data Book, Part 1.* (IUCN, Gland, Switzerland, 1982), and Conservation Monitoring Center, IUCN (IUCN, unpublished data, Cambridge, England, October 1985).

The Species Conservation Monitoring Unit of IUCN maintains a data base of animals that are threatened in the wild. The following six categories are used to classify mammals:

1. *Endangered.* "Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating." Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. Also included are taxa that are possibly already extinct but have definitely been seen in the wild in the past 50 years.
2. *Vulnerable.* "Taxa believed likely to move into the Endangered category in the near future if the causal factors continue operating." Included are taxa of which most or all the populations are decreasing because

of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security has not yet been assured; and taxa with populations that are still abundant but are under threat from severe adverse factors throughout their range.

3. *Rare.* "Taxa with small world populations that are not at present Endangered or Vulnerable, but are at risk." These taxa are usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range.
4. *Indeterminate.* "Taxa known to be Endangered, Vulnerable, or Rare but where there is not enough information to say which of the three categories is appropriate."
5. *Out of Danger.* "Taxa formerly included in one of the above categories, but which are now considered relatively secure because effective conservation measures have been taken or the previous threat to their survival has been removed."
6. *Insufficiently Known.* "Taxa that are suspected but not definitely known to belong to any of the above categories because of lack of information."

In practice, the Endangered and Vulnerable categories may include taxa whose populations are beginning to recover as a result of remedial action but whose recovery is insufficient to justify their transfer to another category.

The total number of mammal species that are threatened globally include Endangered, Vulnerable, Rare, Indeterminate, and Insufficiently Known species.

The total number of mammal species includes species that were introduced to a country, but the number of threatened species excludes introduced species.

The data exclude cetaceans (whales and porpoises). The IUCN notes that the total number of the bat, insectivore, and rodent species may be underreported.

Although the listing of globally threatened species is based on the judgment of many experts working in the field and has taken years to compile, it is under continuous revision as new species are discovered and as more mammals become threatened.

# 8. Energy and Minerals

The tables in this section focus on the production and consumption of commercial energy and minerals. One table presents data on nuclear generation and radioactive wastes. Future editions of *World Resources* will include data on hydropower, coal, petroleum, and renewable sources of energy.

After the petroleum price increases of 1974, a number of countries greatly increased their energy production. Congo, for example, increased energy production from 1 to 229 petajoules: a 229-fold increase in 14 years. Cameroon, Ivory Coast, Guatemala, Ecuador, Malaysia, and Norway reported 10-fold increases during the same period.

The consumption figures reflect a different pattern. Many non-industrialized, petroleum-rich countries greatly increased domestic consumption. Saudi Arabia's consumption increased by a factor of 11; Libya's, by 13. In contrast, many industrialized nations reduced consumption. The United States' consumption declined by 2 percent over this period; consumption per constant dollar of Gross National Product declined by 30 percent.

Imports as a percentage of consumption is an indicator of energy self-sufficiency. The numerator can be positive (a net importer of energy) or negative (a net exporter of energy); the denominator (consumption) is always positive. The ratio, therefore, can be either positive or negative. Norway, for example, imported 61 percent of its energy in 1970. By 1983, Norway exported the equivalent of three times its consumption. Oman exported 235 times its consumption in 1970; 35 times its consumption in 1983. This ratio should not normally exceed a positive 100 percent. A country with a figure greater than 100 percent may have imported more energy in a given year than was consumed in that year, or neglected to account for exports of refined products produced with imported fuels, or misreported its consumption.

There is no single best source of international energy data. The U.N. Statistical Office, the source for Tables 8.1 and 8.2, compiles data from questionnaires sent to all national governments. Other information is gathered from national statistical yearbooks, trade literature, and special energy surveys. The U.N. Statistical Office also gets price data from OECD and the U.S. Department of Energy, which in turn gets much of its information from special reports and country statistical yearbooks. The major petroleum companies (British Petroleum, Texaco, Royal Dutch/Shell, and others) also maintain extensive energy data bases. Despite this large and growing effort, there are serious gaps in energy data. Patterns of energy consumption broken down by commercial, residential, industrial, and transport use are virtually non-existent outside the industrialized countries, and data for even these countries have undergone extensive revisions in the past few years.

The most difficult problem in data collection is gathering data on renewable energy sources, particularly fuelwood and crop and animal residues used for cooking and heating in developing countries. Currently, these data are estimated on the basis of the amount of wood consumed by a family or household unit during the year, multiplied by the number of such units in a country, and increased from year to year based on the rate of population growth. These data have been included only in calculating total energy requirements in Table 8.2. For countries such as Tanzania, Zaire, Nepal, Bangladesh, and even Nigeria (a major oil producer and consumer), the non-commercial fuels are a major component of national energy use. Libya, rich in petroleum and poor in biomass resources, reports very little non-commercial fuel use.

For many countries the production of minerals is as important to their economies as the production of energy. The U.S. Bureau of Mines maintains an international data base for more than 30 metals, 28 non-metals, and 7 mineral fuels. The three minerals, ten ores, and two primary metals listed in Table 8.4 were selected on the basis of importance to national economies and international trade. While world mineral production is dominated by a few major producers, many of these are small countries. Morocco, Tunisia, Jordan, Togo, Nauru, Senegal, and Christmas Island are all major producers of phosphate rock, the principal source of phosphate fertilizers.

Consumption of materials, shown in Table 8.5, is dominated by the major industrialized countries. Only data for metals consumption are available on a country-by-country basis and over time. Metric tons of metal consumed per million dollars of GNP is an important indicator of the intensity of a metal's use.

# Table 8.1 PRODUCTION OF COMMERCIAL ENERGY, 1970–83

| | Total | | Solid | | Liquid | | Gaseous | | Primary Electricity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 |
| **WORLD** | **262856** | **27** | **79415** | **26** | **118483** | **18** | **54451** | **42** | **10508** | **133** |
| **AFRICA** | **14570** | **2** | **3224** | **106** | **9944** | **-20** | **1210** | **1471** | **193** | **114** |
| Algeria | 2493 | 17 | 0 | 0 | 1976 | -4 | 516 | 706 | 1 | -50 |
| Angola | 362 | 65 | X | X | 354 | 64 | 4 | 100 | 5 | 150 |
| Benin | X | X | X | X | X | X | X | X | X | X |
| Botswana | X | X | X | X | X | X | X | X | X | X |
| Burkina Faso | X | X | X | X | X | X | X | X | X | X |
| Burundi | 0 | X | 0 | X | 0 | X | 0 | X | 0 | X |
| Cameroon | 245 | 6025 | X | X | 239 | X | X | X | 6 | 50 |
| Cape Verde | X | X | X | X | X | X | X | X | X | X |
| Central African Rep | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chad | X | X | X | X | X | X | X | X | X | X |
| Comoros | X | X | X | X | X | X | X | X | X | X |
| Congo | 229 | 22800 | X | X | 229 | 22800 | 0 | 0 | 1 | NM |
| Djibouti | X | X | X | X | X | X | X | X | X | X |
| Egypt | 1655 | 130 | X | X | 1553 | 122 | 59 | 1867 | 43 | 153 |
| Equatorial Guinea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ethiopia | 2 | 100 | X | X | X | X | X | X | 2 | 100 |
| Gabon | 344 | 48 | X | X | 337 | 46 | 6 | 500 | 1 | NM |
| Gambia | X | X | X | X | X | X | X | X | X | X |
| Ghana | 12 | 20 | X | X | 3 | X | X | X | 9 | -10 |
| Guinea | 0 | X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Guinea-Bissau | X | X | X | X | X | X | X | X | X | X |
| Ivory Coast | 56 | 5500 | X | X | 49 | X | 0 | X | 6 | 500 |
| Kenya | 6 | 500 | X | X | X | X | X | X | 6 | 500 |
| Lesotho | X | X | X | X | X | X | X | X | X | X |
| Liberia | 1 | 0 | X | X | X | X | X | X | X | X |
| Libya | 2694 | -60 | X | X | 2310 | -66 | 384 | NM | X | X |
| Madagascar | 1 | NM | X | X | X | X | X | X | 1 | NM |
| Malawi | 2 | NM | X | X | X | X | X | X | 2 | NM |
| Mali | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | X | X | X | X | X | X | X | X | X | X |
| Mauritius | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 30 | 43 | 24 | 85 | 1 | -50 | 3 | 50 | 2 | -60 |
| Mozambique | 33 | 200 | 11 | 10 | X | X | X | X | 22 | 2100 |
| Niger | 1 | X | 1 | X | X | X | X | X | X | X |
| Nigeria | 2836 | 22 | 1 | -50 | 2606 | 13 | 220 | 5400 | 9 | 80 |
| Rwanda | 1 | NM | X | X | X | X | 0 | 0 | 1 | NM |
| Senegal | X | X | X | X | X | X | X | X | X | X |
| Sierra Leone | X | X | X | X | X | X | X | X | X | X |
| Somalia | X | X | X | X | X | X | X | X | X | X |
| South Africa | 3103 | 118 | 3101 | 118 | X | X | X | X | 3 | NM |
| Sudan | 2 | NM | X | X | X | X | X | X | 2 | NM |
| Swaziland | X | X | X | X | X | X | X | X | X | X |
| Tanzania, United Rep | 2 | 100 | 0 | 0 | X | X | X | X | 2 | 100 |
| Togo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tunisia | 255 | 44 | X | X | 238 | 34 | 18 | NM | 0 | 0 |
| Uganda | 2 | -33 | X | X | X | X | X | X | 2 | -33 |
| Zaire | 68 | 386 | 4 | 33 | 49 | X | X | X | 15 | 36 |
| Zambia | 47 | 161 | 11 | -27 | X | X | X | X | 36 | 1700 |
| Zimbabwe | 84 | -31 | 70 | -32 | X | X | X | X | 13 | -32 |
| **NORTH AMERICA** | **72233** | **4** | **18388** | **19** | **30527** | **13** | **19789** | **-22** | **3528** | **118** |
| Barbados | 3 | NM | X | X | 2 | NM | X | X | X | X |
| Canada | 8236 | 37 | 1061 | 196 | 3299 | 11 | 2740 | 30 | 1136 | 100 |
| Costa Rica | 9 | 200 | X | X | X | X | X | X | 9 | 200 |
| Cuba | 32 | 357 | X | X | 32 | 357 | 0 | X | 0 | 0 |
| Dominican Rep | 3 | NM | X | X | X | X | X | X | 3 | NM |
| El Salvador | 5 | 150 | X | X | X | X | X | X | 5 | 150 |
| Guatemala | 27 | 2600 | X | X | 26 | X | X | X | 1 | 0 |
| Haiti | 1 | X | X | X | X | X | X | X | 1 | X |
| Honduras | 3 | 200 | X | X | X | X | X | X | 3 | 200 |
| Jamaica | 1 | NM | X | X | X | X | 0 | 0 | 1 | NM |
| Mexico | 7615 | 383 | 163 | 163 | 6324 | 526 | 1048 | 132 | 80 | 48 |
| Nicaragua | 2 | 100 | X | X | X | X | X | X | 2 | 100 |
| Panama | 3 | 200 | X | X | X | X | X | X | 3 | 200 |
| Trinidad and Tobago | 472 | 24 | X | X | 352 | 14 | 120 | 64 | X | X |
| United States | 55820 | -9 | 17164 | 14 | 20493 | -10 | 15880 | -31 | 2283 | 132 |
| **SOUTH AMERICA** | **10088** | **-12** | **362** | **96** | **7356** | **-29** | **1513** | **112** | **857** | **276** |
| Argentina | 1664 | 52 | 12 | -20 | 1117 | 29 | 457 | 119 | 79 | 1217 |
| Bolivia | 144 | 177 | X | X | 51 | 6 | 88 | 8700 | 4 | 100 |
| Brazil | 1473 | 169 | 141 | 147 | 721 | 110 | 65 | 2067 | 546 | 279 |
| Chile | 191 | 7 | 29 | -28 | 93 | 24 | 37 | -23 | 32 | 100 |
| Colombia | 770 | 21 | 176 | 167 | 343 | -31 | 181 | 229 | 71 | 223 |
| Ecuador | 521 | 4636 | X | X | 513 | 5600 | 1 | 0 | 6 | 500 |
| Guyana | 0 | X | 0 | X | 0 | X | 0 | X | 0 | X |
| Paraguay | 3 | 200 | X | X | X | X | X | X | 3 | 200 |
| Peru | 431 | 129 | 2 | -60 | 362 | 135 | 40 | 150 | 26 | 86 |
| Suriname | 4 | 0 | X | X | 1 | NM | X | X | 3 | -25 |
| Uruguay | 26 | 550 | X | X | X | X | X | X | 26 | 550 |
| Venezuela | 4862 | -44 | 1 | 0 | 4155 | -50 | 644 | 69 | 61 | 307 |

# Table 8.1

| | Total | | Solid | | Liquid | | Gaseous | | Primary Electricity | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (peta-joules) | Percent Change Over 1970 |
| **ASIA** | **61210** | **30** | **20890** | **81** | **35076** | **4** | **3625** | **220** | **1619** | **171** |
| Afghanistan | 107 | 6 | 5 | 0 | 0 | 0 | 99 | 4 | 3 | 200 |
| Bahrain | 226 | 28 | X | X | 100 | -39 | 126 | 800 | X | X |
| Bangladesh | 82 | X | X | X | 0 | X | 79 | X | 2 | X |
| Bhutan | X | X | X | X | X | X | X | X | X | X |
| Burma | 88 | 132 | 1 | NM | 64 | 88 | 19 | 850 | 4 | 300 |
| China | 20005 | 125 | 14698 | 98 | 4520 | 246 | 475 | 324 | 311 | 320 |
| Cyprus | X | X | X | X | X | X | X | X | X | X |
| India | 4683 | 136 | 3309 | 110 | 1074 | 270 | 107 | 463 | 194 | 94 |
| Indonesia | 3521 | 88 | 14 | 180 | 2811 | 55 | 690 | 1368 | 5 | 25 |
| Iran | 5591 | -35 | 23 | 44 | 5280 | -35 | 264 | -42 | 23 | 283 |
| Iraq | 2024 | -38 | X | X | 2005 | -38 | 17 | -45 | 2 | X |
| Israel | 3 | -99 | X | X | 1 | -100 | 2 | -60 | X | X |
| Japan | 1284 | -14 | 474 | -55 | 19 | -44 | 90 | -13 | 702 | 129 |
| Jordan | X | X | X | X | X | X | X | X | X | X |
| *Kampuchea, Dem* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| Korea, Dem People's Rep | 1401 | 79 | 1307 | 77 | X | X | X | X | 94 | 129 |
| Korea, Rep | 407 | 46 | 365 | 33 | X | X | X | X | 42 | 950 |
| Kuwait | 2460 | -63 | X | X | 2370 | -63 | 90 | 13 | X | X |
| Lao People's Dem Rep | 4 | NM | 0 | 0 | X | X | X | X | 4 | NM |
| Lebanon | 2 | -33 | X | X | X | X | X | X | 2 | -33 |
| Malaysia | 827 | 1780 | X | X | 808 | 2084 | 13 | 333 | 5 | 25 |
| Mongolia | 52 | 148 | 52 | 148 | X | X | X | X | X | X |
| Nepal | 1 | NM | X | X | X | X | X | X | 1 | NM |
| Oman | 796 | 13 | X | X | 796 | 13 | X | X | X | X |
| Pakistan | 420 | 158 | 38 | 3 | 25 | 25 | 319 | 232 | 38 | 245 |
| Philippines | 77 | 863 | 20 | 1900 | 31 | NM | X | X | 25 | 213 |
| Qatar | 860 | 10 | X | X | 649 | -12 | 210 | 438 | X | X |
| Saudi Arabia | 11293 | 39 | X | X | 11243 | 38 | 50 | NM | X | X |
| Singapore | X | X | X | X | X | X | X | X | X | X |
| Sri Lanka | 4 | 33 | X | X | X | X | X | X | 4 | 33 |
| Syrian Arab Rep | 414 | 129 | X | X | 399 | 120 | 3 | NM | 12 | NM |
| Thailand | 102 | 827 | 22 | 450 | 8 | NM | 57 | NM | 15 | 150 |
| Turkey | 453 | 29 | 318 | 68 | 94 | -38 | 0 | X | 41 | 273 |
| United Arab Emirates | 2939 | 82 | X | X | 2396 | 49 | 542 | 5922 | X | X |
| Viet Nam | 182 | 102 | 176 | 100 | X | X | X | X | 6 | 200 |
| Yemen | X | X | X | X | X | X | X | X | X | X |
| Yemen, Dem | X | X | X | X | X | X | X | X | X | X |
| **EUROPE** | **40004** | **50** | **19230** | **-1** | **8417** | **415** | **9127** | **114** | **3230** | **127** |
| Albania | 198 | 154 | 25 | 178 | 149 | 137 | 16 | 300 | 8 | 300 |
| Austria | 253 | -23 | 40 | -26 | 54 | -55 | 49 | -36 | 110 | 43 |
| Belgium | 293 | -13 | 201 | -40 | X | X | 1 | -50 | 91 | 9000 |
| Bulgaria | 552 | 17 | 478 | 10 | 13 | -7 | 4 | -76 | 56 | 600 |
| Czechoslovakia | 1983 | 6 | 1922 | 6 | 4 | -56 | 20 | -46 | 36 | 177 |
| *Denmark* | *92* | *9100* | *0* | *-100* | *92* | *NM* | *X* | *X* | *0* | *0* |
| Finland | 120 | 243 | 11 | 1000 | X | X | X | X | 108 | 218 |
| France | 1671 | -6 | 592 | -49 | 100 | -21 | 231 | -15 | 748 | 228 |
| German Dem Rep | 2688 | 13 | 2491 | 6 | 3 | -25 | 145 | 625 | 50 | 733 |
| Germany, Fed Rep | 4624 | -9 | 3509 | -17 | 175 | -46 | 635 | 38 | 306 | 256 |
| Greece | 231 | 285 | 167 | 234 | 53 | X | 3 | X | 8 | -20 |
| Hungary | 656 | 8 | 280 | -30 | 118 | 34 | 249 | 118 | 10 | NM |
| Ireland | 126 | 147 | 39 | -20 | X | X | 83 | X | 4 | 33 |
| Italy | 809 | 7 | 18 | -22 | 101 | 58 | 501 | 1 | 190 | 12 |
| *Luxembourg* | *2* | *-33* | *X* | *X* | *X* | *X* | *X* | *X* | *2* | *-33* |
| Malta | X | X | X | X | X | X | X | X | X | X |
| Netherlands | 3215 | 143 | 0 | -100 | 511 | 523 | 2691 | 141 | 13 | 1200 |
| Norway | 2734 | 1148 | 15 | 15 | 1305 | NM | 1032 | NM | 382 | 85 |
| Poland | 5010 | 31 | 4820 | 33 | 11 | -42 | 166 | -11 | 12 | 71 |
| Portugal | 34 | 17 | 5 | -38 | X | X | X | X | 29 | 38 |
| Romania | 2707 | 42 | 584 | 80 | 518 | -12 | 1570 | 60 | 36 | 260 |
| Spain | 812 | 96 | 554 | 83 | 127 | 2017 | 0 | -100 | 132 | 27 |
| Sweden | 381 | 152 | 0 | -100 | 1 | NM | X | X | 380 | 153 |
| Switzerland | 183 | 59 | X | X | X | X | X | X | 183 | 59 |
| United Kingdom | 9633 | 127 | 2896 | -21 | 4906 | 69986 | 1628 | 274 | 203 | 78 |
| Yugoslavia | 982 | 56 | 584 | 41 | 176 | 43 | 105 | 169 | 117 | 121 |
| **USSR** | **60535** | **70** | **14630** | **9** | **26311** | **75** | **18638** | **179** | **957** | **107** |
| **OCEANIA** | **4216** | **127** | **2692** | **99** | **852** | **133** | **549** | **815** | **124** | **57** |
| Australia | 3969 | 127 | 2636 | 103 | 823 | 127 | 463 | 727 | 47 | 42 |
| Fiji | 0 | X | 0 | X | 0 | X | 0 | X | 0 | X |
| *New Zealand* | *245* | *127* | *56* | *-2* | *29* | *1350* | *85* | *2025* | *75* | *67* |
| Papua New Guinea | 1 | NM | X | X | X | X | X | X | 1 | NM |
| Solomon Islands | X | X | X | X | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | | | | | |

**Source:** U.N. Statistical Office.
0 = zero or less than one-half the unit of measure; X = not available; NM = not meaningful.
For additional information, see Sources and Technical Notes.

# Table 8.2 CONSUMPTION OF COMMERCIAL ENERGY AND TOTAL

| | Total: 1983 (peta-joules) | Total: Percent Change Over 1970 | Consumption Per Capita: 1983 (giga-joules) | Consumption Per Capita: Percent Change Over 1970 | Consumption Per Constant (1975) $US of GNP: 1983 (mega-joules) | Consumption Per Constant (1975) $US of GNP: Percent Change Over 1970 | Imports as Percentage of Consumption: 1983 | Imports as Percentage of Consumption: 1970 | Total Requirements: 1983 (peta-joules) | Total Requirements: Percent Change Over 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| **WORLD** | **249813** | **32** | **53** | **4** | | | | | **292650** | **38** |
| **AFRICA** | **6368** | **114** | **12** | **47** | | | **-121** | **-376** | **11109** | **81** |
| Algeria | 376 | 154 | 18 | 70 | 15878 | 20 | -501 | -1356 | 392 | 139 |
| Angola | 31 | 19 | 4 | -20 | 12310 | 99 | -1006 | -731 | 119 | 31 |
| Benin | 5 | 25 | 1 | -10 | 6428 | -24 | 120 | 100 | 44 | 47 |
| Botswana | X | X | X | X | X | X | X | X | X | X |
| Burkina Faso | 6 | 200 | 1 | 130 | 7307 | 111 | 100 | 100 | 75 | 50 |
| Burundi | 2 | 100 | 0 | 58 | 3576 | 41 | 100 | 100 | 36 | 33 |
| Cameroon | 120 | 823 | 13 | 578 | 26499 | 341 | -88 | 69 | 213 | 154 |
| Cape Verde | 1 | NM | 3 | NM | 9662 | X | 100 | NM | 1 | 0 |
| Central African Rep | 3 | 0 | 1 | -23 | 7782 | -13 | 100 | 100 | 28 | 33 |
| Chad | 3 | 50 | 1 | 14 | 11472 | 176 | 100 | 100 | 78 | 34 |
| Comoros | 1 | NM | 2 | NM | 11710 | X | 100 | NM | 1 | NM |
| Congo | 5 | 0 | 3 | -27 | 3729 | -63 | -4480 | 80 | 22 | 22 |
| Djibouti | 6 | 500 | 22 | 243 | X | X | 117 | 100 | 6 | 500 |
| Egypt | 759 | 199 | 17 | 121 | 27571 | 20 | -104 | -180 | 895 | 179 |
| Equatorial Guinea | 1 | 0 | 3 | -22 | X | X | 100 | 100 | 5 | 25 |
| Ethiopia | 25 | 32 | 1 | -3 | 7403 | -10 | 100 | 116 | 307 | 33 |
| Gabon | 32 | 146 | 28 | 107 | 23732 | 81 | -953 | -1669 | 47 | 96 |
| Gambia | 2 | 100 | 3 | 52 | 14837 | 22 | 100 | 100 | 10 | 43 |
| Ghana | 35 | -17 | 3 | -43 | 8684 | -6 | 89 | 81 | 128 | 10 |
| Guinea | 13 | 18 | 3 | -10 | 9880 | -15 | 92 | 100 | 43 | 30 |
| Guinea-Bissau | 1 | 0 | 1 | -39 | 5225 | -21 | 100 | 100 | 5 | 25 |
| Ivory Coast | 53 | 66 | 6 | 0 | 11022 | -5 | 8 | 103 | 141 | 83 |
| Kenya | 53 | 56 | 3 | -7 | 11731 | -32 | 106 | 112 | 371 | 83 |
| Lesotho | X | X | X | X | X | X | X | X | X | X |
| Liberia | 22 | 16 | 11 | -23 | 32150 | -10 | 105 | -116 | 64 | 28 |
| Libya | 560 | 1336 | 168 | 753 | 39774 | 1408 | -362 | -17362 | 565 | 1214 |
| Madagascar | 16 | 23 | 2 | -13 | 9192 | 21 | 125 | 92 | 74 | -16 |
| Malawi | 9 | 50 | 1 | 3 | 10912 | -24 | 78 | 83 | 140 | 211 |
| Mali | 6 | 100 | 1 | 50 | 7086 | 27 | 100 | 100 | 48 | 45 |
| Mauritania | 9 | 50 | 5 | 5 | 15820 | 16 | 100 | 100 | 9 | 50 |
| Mauritius | 8 | 0 | 8 | -16 | 9070 | -45 | 100 | 100 | 26 | 8 |
| Morocco | 195 | 132 | 9 | 61 | 15128 | 27 | 93 | 83 | 211 | 109 |
| Mozambique | 37 | 12 | 3 | -31 | 12162 | 34 | 19 | 70 | 226 | 85 |
| Niger | 10 | 233 | 2 | 139 | 10910 | 163 | 90 | 100 | 43 | 65 |
| Nigeria | 498 | 523 | 6 | 300 | 14527 | 321 | -465 | -2793 | 1287 | 114 |
| Rwanda | 3 | 200 | 1 | 96 | 3708 | 62 | 100 | 100 | 53 | 23 |
| Senegal | 29 | 93 | 5 | 25 | 12701 | 39 | 103 | 107 | 66 | 50 |
| Sierra Leone | 7 | -30 | 2 | -43 | 10229 | -43 | 171 | 120 | 85 | 31 |
| Somalia | 16 | 433 | 3 | 182 | 19935 | 294 | 106 | 100 | 66 | 113 |
| South Africa | 2927 | 75 | 95 | 30 | 70077 | 22 | -9 | 16 | 3068 | 71 |
| Sudan | 47 | -23 | 2 | -48 | 7638 | -55 | 106 | 110 | 418 | 35 |
| Swaziland | X | X | X | X | X | X | X | X | X | X |
| Tanzania, United Rep | 26 | 18 | 1 | -24 | 8921 | -16 | 104 | 109 | 412 | 51 |
| Togo | 16 | 300 | 6 | 193 | 24521 | 210 | 63 | 100 | 22 | 214 |
| Tunisia | 127 | 195 | 18 | 120 | 19394 | 29 | -94 | -293 | 152 | 145 |
| Uganda | 10 | -50 | 1 | -66 | X | X | 80 | 90 | 257 | 32 |
| Zaire | 62 | 44 | 2 | 0 | 17768 | 29 | -8 | 70 | 380 | 42 |
| Zambia | 65 | 38 | 10 | -7 | 27328 | 17 | 26 | 64 | 237 | 166 |
| Zimbabwe | 113 | -12 | 14 | -43 | 26965 | -45 | 26 | 5 | 207 | -10 |
| **NORTH AMERICA** | **76120** | **4** | **195** | **-15** | | | **7** | **7** | **86204** | **11** |
| Barbados | 9 | 50 | 35 | 38 | 19251 | 9 | 67 | 117 | 12 | 20 |
| Canada | 6993 | 26 | 280 | 8 | 37196 | -15 | -18 | -9 | 9697 | 40 |
| Costa Rica | 39 | 105 | 16 | 44 | 18771 | 42 | 82 | 84 | 79 | 80 |
| Cuba | 402 | 61 | 41 | 39 | X | X | 102 | 100 | 568 | 24 |
| Dominican Rep | 90 | 125 | 15 | 62 | 18793 | 7 | 104 | 100 | 135 | 96 |
| El Salvador | 28 | 40 | 5 | -4 | 17759 | 21 | 89 | 95 | 90 | 58 |
| Guatemala | 47 | 57 | 6 | 6 | 10436 | -5 | 47 | 100 | 129 | 61 |
| Haiti | 10 | 100 | 2 | 47 | 11312 | 39 | 90 | 100 | 65 | 41 |
| Honduras | 27 | 50 | 7 | -3 | 18242 | -1 | 93 | 100 | 81 | 69 |
| Jamaica | 88 | 33 | 39 | 10 | 36979 | 40 | 103 | 103 | 96 | 26 |
| Mexico | 3821 | 145 | 51 | 67 | 32356 | 32 | -96 | 1 | 4216 | 130 |
| Nicaragua | 26 | 37 | 9 | -8 | 19363 | 18 | 104 | 95 | 63 | 54 |
| Panama | 44 | 26 | 21 | -8 | 17097 | -31 | 102 | 114 | 73 | 43 |
| Trinidad and Tobago | 187 | 42 | 171 | 33 | 52972 | -12 | -60 | -184 | 189 | 37 |
| United States | 63738 | -2 | 273 | -14 | 33381 | -30 | 13 | 7 | 70131 | 4 |
| **SOUTH AMERICA** | **7226** | **73** | **28** | **28** | | | **-26** | **-162** | **12107** | **82** |
| Argentina | 1492 | 34 | 50 | 9 | 40104 | 23 | 0 | 10 | 1782 | 46 |
| Bolivia | 61 | 110 | 10 | 51 | 28931 | 80 | -128 | -76 | 86 | 95 |
| Brazil | 2511 | 106 | 19 | 52 | 16006 | -2 | 59 | 61 | 6091 | 101 |
| Chile | 311 | -2 | 27 | -21 | 36787 | -8 | 39 | 44 | 441 | 10 |
| Colombia | 733 | 98 | 27 | 49 | 42783 | 11 | 0 | -67 | 1069 | 97 |
| Ecuador | 170 | 247 | 19 | 135 | 29995 | 51 | -176 | 80 | 242 | 169 |
| Guyana | 22 | 0 | 24 | -23 | 58063 | -2 | 100 | 100 | 29 | -3 |
| Paraguay | 20 | 100 | 6 | 32 | 7759 | -17 | 90 | 100 | 73 | 66 |
| Peru | 345 | 47 | 18 | 4 | 23349 | 21 | -20 | 20 | 481 | 44 |
| Suriname | 26 | 4 | 74 | 10 | 40454 | -37 | 88 | 88 | 34 | -3 |
| Uruguay | 61 | -16 | 21 | -21 | 16303 | -26 | 66 | 107 | 150 | 60 |
| Venezuela | 1468 | 104 | 85 | 30 | 49165 | 42 | -212 | -1070 | 1626 | 111 |

# REQUIREMENTS, 1970–83

## Table 8.2

| | Total | | Consumption Per Capita | | Consumption Per Constant (1975) $US of GNP | | Imports as Percentage of Consumption | | Total Requirements | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1983 (peta-joules) | Percent Change Over 1970 | 1983 (giga-joules) | Percent Change Over 1970 | 1983 (mega-joules) | Percent Change Over 1970 | 1983 | 1970 | 1983 (peta-joules) | Percent Change Over 1970 |
| **ASIA** | **49927** | **89** | **18** | **45** | | | **-16** | **-69** | **61298** | **81** |
| Afghanistan | 28 | 56 | 2 | 36 | 12438 | 15 | -286 | -456 | 85 | 52 |
| Bahrain | 141 | 729 | 355 | 360 | X | X | -9 | -588 | 141 | 729 |
| Bangladesh | 33 | X | 0 | X | 1553 | X | 197 | X | 447 | X |
| Bhutan | X | X | 0 | X | X | X | X | X | 29 | 26 |
| Burma | 73 | 55 | 2 | 13 | 12768 | -16 | 4 | 36 | 255 | 47 |
| China | 18438 | 118 | 18 | 74 | 71644 | 1 | -5 | -1 | 20757 | 109 |
| Cyprus | 36 | 64 | 55 | 55 | 27454 | -19 | 103 | 100 | 36 | 64 |
| India | 4961 | 122 | 7 | 67 | 41993 | 38 | 12 | 19 | 7704 | 85 |
| Indonesia | 1121 | 176 | 7 | 108 | 23265 | 18 | -197 | -345 | 2285 | 75 |
| Iran | 1388 | 74 | 33 | 17 | X | X | -289 | -975 | 1447 | 75 |
| Iraq | 270 | 62 | 18 | 3 | X | X | -634 | -1855 | 276 | 64 |
| Israel | 298 | 60 | 72 | 15 | 18595 | -9 | 109 | 6 | 298 | 59 |
| Japan | 11836 | 21 | 100 | 6 | 16720 | -32 | 94 | 93 | 13487 | 28 |
| Jordan | 88 | 389 | 27 | 246 | 37584 | 78 | 113 | 111 | 88 | 389 |
| Kampuchea, Dem | 1 | -92 | 0 | -92 | X | X | 0 | 133 | 46 | -16 |
| Korea, Dem People's Rep | 1532 | 84 | 80 | 33 | X | X | 8 | 6 | 1806 | 86 |
| Korea, Rep | 1694 | 177 | 43 | 122 | 46403 | 5 | 87 | 62 | 1861 | 176 |
| Kuwait | 248 | 134 | 153 | 8 | 13210 | 25 | -804 | -5943 | 248 | 134 |
| Lao People's Dem Rep | 9 | 13 | 2 | -19 | X | X | 44 | 100 | 53 | 56 |
| Lebanon | 57 | 16 | 22 | 9 | X | X | 96 | 94 | 65 | 8 |
| Malaysia | 390 | 119 | 26 | 60 | 24741 | -12 | -105 | 108 | 476 | 101 |
| Mongolia | 83 | 159 | 46 | 80 | X | X | 37 | 34 | 97 | 120 |
| Nepal | 7 | 40 | 0 | 2 | 3562 | 2 | 86 | 80 | 148 | 38 |
| Oman | 22 | 633 | 19 | 324 | 7890 | 247 | -3518 | -23467 | 22 | 633 |
| Pakistan | 637 | 97 | 7 | 35 | 33844 | 1 | 39 | 55 | 936 | 649 |
| Philippines | 478 | 63 | 9 | 17 | 20966 | -18 | 90 | 109 | 866 | 56 |
| Qatar | 232 | 440 | 826 | 113 | 132534 | 478 | -270 | -1712 | 232 | 440 |
| Saudi Arabia | 1097 | 1306 | 105 | 675 | 19753 | 339 | -903 | -10085 | 1097 | 1306 |
| Singapore | 392 | 409 | 156 | 321 | 36654 | 72 | 190 | 125 | 392 | 409 |
| Sri Lanka | 62 | 38 | 4 | 9 | 14294 | -22 | 110 | 120 | 146 | 32 |
| Syrian Arab Rep | 267 | 287 | 27 | 147 | 30585 | 33 | -32 | -146 | 296 | 329 |
| Thailand | 511 | 161 | 10 | 91 | 21537 | 19 | 81 | 104 | 952 | 100 |
| Turkey | 1039 | 111 | 22 | 56 | 21926 | 14 | 64 | 33 | 1422 | 80 |
| United Arab Emirates | 673 | 4106 | 563 | 684 | 37688 | X | -342 | -9994 | 673 | 4106 |
| Viet Nam | 210 | -43 | 4 | -58 | X | X | 14 | 76 | 431 | -18 |
| Yemen | 36 | 1700 | 6 | 1297 | 21183 | 477 | 97 | 100 | 36 | 1700 |
| Yemen, Dem | 49 | 345 | 24 | 232 | 79662 | X | 104 | 318 | 52 | 300 |
| **EUROPE** | **59784** | **19** | **122** | **11** | | | **36** | **54** | **68019** | **25** |
| Albania | 107 | 182 | 37 | 106 | X | X | 4 | -5 | 141 | 139 |
| Austria | 783 | 10 | 105 | 9 | 16939 | -26 | 66 | 59 | 1054 | 16 |
| Belgium | 1432 | -10 | 145 | -12 | 19939 | -34 | 91 | 90 | 1651 | 4 |
| Bulgaria | 1471 | 57 | 161 | 46 | X | X | 67 | 50 | 1618 | 67 |
| Czechoslovakia | 2841 | 25 | 183 | 16 | X | X | 35 | 20 | 2941 | 27 |
| Denmark | 650 | -17 | 126 | -21 | 14913 | -35 | 76 | 104 | 653 | -17 |
| Finland | 633 | 15 | 131 | 10 | 18829 | -22 | 88 | 104 | 916 | 30 |
| France | 6101 | 7 | 112 | 0 | 14858 | -27 | 76 | 79 | 7948 | 25 |
| German Dem Rep | 3569 | 16 | 214 | 19 | X | X | 29 | 22 | 3693 | 20 |
| Germany, Fed Rep | 9954 | 8 | 162 | 7 | 19818 | -18 | 51 | 51 | 10712 | 13 |
| Greece | 628 | 120 | 64 | 97 | 23891 | 41 | 72 | 87 | 666 | 100 |
| Hungary | 1167 | 37 | 108 | 31 | 85809 | -36 | 53 | 34 | 1218 | 39 |
| Ireland | 328 | 47 | 93 | 24 | 34666 | 6 | 61 | 80 | 342 | 45 |
| Italy | 5060 | 22 | 89 | 15 | 22122 | -9 | 88 | 94 | 5549 | 21 |
| Luxembourg | 112 | -34 | 308 | -38 | 29089 | -65 | 99 | 98 | 118 | -33 |
| Malta | 13 | 44 | 34 | 25 | 15359 | -49 | 100 | 100 | 13 | 44 |
| Netherlands | 2693 | 54 | 187 | 39 | 27758 | 19 | -13 | 51 | 2723 | 55 |
| Norway | 696 | 35 | 169 | 26 | 19428 | -15 | -293 | 61 | 1595 | 59 |
| Poland | 4731 | 39 | 128 | 23 | X | X | -3 | -11 | 4786 | 39 |
| Portugal | 388 | 107 | 39 | 80 | 20675 | 32 | 101 | 92 | 460 | 89 |
| Romania | 2972 | 66 | 131 | 49 | 88195 | X | 13 | -2 | 3100 | 66 |
| Spain | 2398 | 65 | 62 | 45 | 20253 | 11 | 75 | 77 | 2718 | 55 |
| Sweden | 1137 | -16 | 137 | -19 | 14776 | -31 | 72 | 94 | 2219 | 27 |
| Switzerland | 693 | 17 | 110 | 16 | 11070 | 1 | 74 | 85 | 1129 | 30 |
| United Kingdom | 7638 | -4 | 137 | -4 | 29167 | -23 | -26 | 53 | 8114 | -1 |
| Yugoslavia | 1550 | 84 | 68 | 64 | 38260 | 5 | 40 | 30 | 1862 | 80 |
| **USSR** | **47230** | **61** | **173** | **43** | **X** | **X** | **-21** | **-15** | **50277** | **61** |
| **OCEANIA** | **3159** | **52** | **131** | **22** | | | **-30** | **14** | **3636** | **52** |
| Australia | 2697 | 52 | 176 | 24 | 23703 | 6 | -43 | 5 | 2929 | 52 |
| Fiji | 9 | 29 | 14 | 1 | 10964 | -23 | 100 | 86 | 17 | 6 |
| New Zealand | 342 | 49 | 106 | 30 | 24253 | 15 | 31 | 54 | 518 | 52 |
| Papua New Guinea | 27 | 145 | 8 | 69 | 19327 | 90 | 96 | 91 | 84 | 62 |
| Solomon Islands | 2 | 100 | 8 | 28 | 20725 | X | 100 | 100 | 4 | 100 |
| **ANTARCTICA** | | | | | | | | | | |

**Source:** U.N. Statistical Office.
0 = zero or less than one-half the unit of measure; X = not available; NM = not meaningful.
For additional information, see Sources and Technical Notes.

# Table 8.3 NUCLEAR POWER AND WASTE GENERATION, 1970–84

| | Number of Operable Reactors | | Installed Capacity (GWe) | | Nuclear as Percent of Total Electricity Generation | | Spent Fuel Inventories (cumulative metric tons of heavy metal) | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1984 | 1970 | 1984 | 1973 | 1984 | 1970 | 1984 |
| **WORLD TOTAL** | **80** | **345** | **16.8** | **226.6** | | | | |
| **MARKET ECONOMIES** | **65** | **285** | **15.2** | **196.7** | | | **6405** | **56654** |
| **Europe** | **44** | **133** | **8.5** | **84.4** | | | **6060** | **34236** |
| Belgium | 1 | 5 | 0.0 | 3.5 | 0 | 51 | | |
| Finland | 0 | 4 | 0.0 | 2.3 | 0 | 42 | | |
| France | 5 | 41 | 1.6 | 33.3 | 8 | 59 | | |
| Germany, Fed Rep | 4 | 16 | 0.9 | 16.1 | 4 | 28 | | |
| Italy | 3 | 3 | 0.6 | 1.3 | 2 | 4 | | |
| Netherlands | 1 | 2 | 0.1 | 0.5 | 2 | 6 | | |
| Spain | 1 | 7 | 0.2 | 4.8 | 8 | 19 | | |
| Sweden | 1 | 11 | 0.0 | 8.4 | 3 | 41 | | |
| Switzerland | 1 | 5 | 0.4 | 2.9 | 16 | 37 | | |
| United Kingdom | 27 | 38 | 4.8 | 10.7 | 10 | 17 | | |
| Yugoslavia | 0 | 1 | 0.0 | 0.6 | 0 | 6 | | |
| **North America** | **16** | **103** | **5.4** | **81.2** | | | **331** | **17745** |
| Canada | 1 | 17 | 0.2 | 10.0 | 6 | 12 | 96 | 6363 |
| United States | 15 | 86 | 5.2 | 71.2 | 4 | 13 | 235 | 11382 |
| **Far East** | **3** | **39** | **0.8** | **27.6** | | | **14** | **3610** |
| Japan | 3 | 31 | 0.8 | 21.8 | 2 | 23 | | |
| Korea, Rep | 0 | 3 | 0.0 | 1.8 | 0 | 22 | | |
| Taiwan | 0 | 5 | 0.0 | 4.0 | 0 | 48 | | |
| **Other** | **2** | **10** | **0.4** | **3.5** | | | **0** | **1063** |
| Argentina | 0 | 2 | 0.0 | 0.9 | 0 | 11 | | |
| Brazil | 0 | 1 | 0.0 | 0.6 | 0 | 0 | | |
| India | 2 | 5 | 0.4 | 1.0 | 4 | 3 | | |
| Pakistan | 0 | 1 | 0.0 | 0.1 | 0 | 4 | | |
| South Africa | 0 | 1 | 0.0 | 0.9 | 0 | 0 | | |
| **NON-MARKET ECONOMIES** | **15** | **60** | **1.6** | **29.9** | | | **X** | **X** |
| Bulgaria | 0 | 4 | 0.0 | 1.8 | 0 | 32 | | |
| Czechoslovakia | 0 | 3 | 0.0 | 1.3 | 0 | 8 | | |
| German Dem Rep | 0 | 5 | 0.0 | 1.8 | 0 | 12 | | |
| Hungary | 0 | 2 | 0.0 | 0.9 | 0 | 10 | | |
| USSR | 15 | 46 | 1.6 | 24.1 | 1 | 8 | | |

**Sources:** U.S. Department of Energy; OECD; *Nucleonics Week; Nuclear Engineering International.*
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 8.4 PRODUCTION OF SELECTED MATERIALS, 1965–83

Annual Production (thousand metric tons)

| ANTIMONY | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Bolivia | 10 | 12 | 12 | 15 | 11 |
| China | 15 | 12 | 12 | 10 | 10 |
| USSR | 6 | 7 | 8 | 8 | 9 |
| South Africa | 13 | 17 | 16 | 13 | 6 |
| Mexico | 4 | 4 | 3 | 2 | 2 |
| Yugoslavia | 3 | 2 | 2 | 2 | 1 |
| Australia | 1 | 1 | 2 | 1 | 1 |
| Thailand | 1 | 2 | 3 | 3 | 1 |
| Turkey | 4 | 3 | 4 | 1 | 1 |
| Morocco | 2 | 2 | 1 | 1 | 1 |
| Czechoslovakia | 1 | 1 | 1 | 1 | 0 |
| Italy | 0 | 1 | 1 | 1 | X |
| Canada | 1 | 0 | 2 | 2 | X |
| **World Total** | **63** | **70** | **70** | **64** | **53** |
| **Major Producers as Percent of World Total** | **96** | **92** | **94** | **95** | **83** |

| BAUXITE | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Australia | 1186 | 9256 | 21003 | 27178 | 24500 |
| Guinea | 1870 | 2490 | 8406 | 11862 | 11080 |
| Jamaica | 8651 | 12010 | 11571 | 12054 | 7300 |
| Brazil | 156 | 500 | 802 | 5538 | 7000 |
| USSR | 4700 | 4300 | 6470 | 6180 | 6180 |
| Yugoslavia | 1574 | 2099 | 2306 | 3138 | 3500 |
| Hungary | 1477 | 2022 | 2890 | 2950 | 2917 |
| Greece | 1270 | 2292 | 3006 | 3286 | 2900 |
| India | 707 | 1370 | 1273 | 1785 | 1923 |
| Guyana | 2919 | 4417 | 3250 | 1844 | 1791 |
| Suriname | 4360 | 6022 | 4928 | 4646 | 1750 |
| France | 2662 | 2992 | 2563 | 1921 | 1716 |
| United States | 1680 | 2115 | 1801 | 1559 | 679 |
| **World Total** | **37460** | **57786** | **76895** | **90795** | **77596** |
| **Major Producers as Percent of World Total** | **89** | **90** | **91** | **92** | **94** |

| CHROMITE | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| USSR | 1270 | 1750 | 2080 | 2450 | 2450 |
| South Africa | 942 | 1427 | 2075 | 3414 | 2232 |
| Albania | 311 | 466 | 779 | 760 | 900 |
| Brazil | 32 | 27 | 702 | 833 | 670 |
| Zimbabwe | 586 | 360 | 590 | 554 | 431 |
| Turkey | 567 | 540 | 720 | 391 | 400 |
| India | 60 | 273 | 500 | 320 | 360 |
| Finland | X | 51 | 332 | 362 | 340 |
| Philippines | 554 | 566 | 520 | 496 | 330 |
| New Caledonia | X | X | 2 | 2 | 91 |
| Iran | 129 | 200 | 210 | 80 | 50 |
| Madagascar | 2 | 105 | 194 | 180 | 42 |
| Greece | 51 | 27 | 73 | 43 | 40 |
| Yugoslavia | 80 | 41 | 2 | X | X |
| **World Total** | **4810** | **6053** | **8296** | **9467** | **8085** |
| **Major Producers as Percent of World Total** | **95** | **96** | **97** | **96** | **95** |

| COPPER | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Chile | 606 | 711 | 828 | 1068 | 1190 |
| United States | 1226 | 1560 | 1282 | 1181 | 1038 |
| USSR | 700 | 570 | 765 | 900 | 1000 |
| Canada | 461 | 610 | 734 | 716 | 625 |
| Zambia | 696 | 684 | 677 | 596 | 543 |
| Zaire | 289 | 387 | 495 | 540 | 535 |
| Poland | 15 | 72 | 230 | 346 | 380 |
| Peru | 180 | 220 | 193 | 367 | 336 |
| Philippines | 63 | 160 | 226 | 305 | 309 |
| Australia | 92 | 158 | 219 | 244 | 256 |
| South Africa | 60 | 149 | 179 | 201 | 211 |
| China | 90 | 100 | 100 | 200 | 200 |
| Japan | 107 | 120 | 85 | 53 | 46 |
| **World Total** | **5044** | **6036** | **7009** | **7739** | **8027** |
| **Major Producers as Percent of World Total** | **91** | **91** | **86** | **87** | **83** |

| IRON | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| USSR | 153432 | 195492 | 232803 | 244713 | 245000 |
| Brazil | 20754 | 40200 | 89894 | 114732 | 89000 |
| Australia | 6803 | 51189 | 97651 | 95534 | 71500 |
| China | 39000 | 40400 | 65000 | 68000 | 71000 |
| India | 23830 | 31366 | 41405 | 41936 | 38800 |
| United States | 88842 | 91201 | 80132 | 70730 | 38600 |
| Canada | 36250 | 47459 | 46868 | 48754 | 33495 |
| South Africa | 5816 | 7728 | 12298 | 26312 | 16605 |
| France | 59532 | 56805 | 49647 | 28981 | 15967 |
| Liberia | 15959 | 23661 | 24000 | 18187 | 14937 |
| Sweden | 29354 | 31509 | 30867 | 27184 | 13212 |
| Venezuela | 17510 | 22100 | 24772 | 16102 | 9715 |
| **World Total** | **620982** | **769163** | **902018** | **895867** | **739133** |
| **Major Producers as Percent of World Total** | **80** | **83** | **88** | **89** | **89** |

Annual Production (thousand metric tons)

| LEAD | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Australia | 368 | 457 | 408 | 397 | 477 |
| United States | 273 | 519 | 564 | 550 | 449 |
| USSR | 350 | 440 | 480 | 420 | 435 |
| Canada | 275 | 353 | 349 | 297 | 252 |
| Peru | 154 | 157 | 184 | 189 | 206 |
| China | 100 | 100 | 100 | 160 | 160 |
| Mexico | 167 | 177 | 179 | 147 | 150 |
| Yugoslavia | 106 | 127 | 127 | 121 | 120 |
| Morocco | 77 | 73 | 64 | 115 | 102 |
| Bulgaria | 100 | 96 | 114 | 116 | 96 |
| Korea, Dem People's Rep | 60 | 70 | 120 | 125 | 95 |
| Sweden | 69 | 78 | 70 | 72 | 65 |
| Namibia | 88 | 73 | 53 | 50 | 38 |
| **World Total** | **2695** | **3394** | **3434** | **3448** | **3324** |
| **Major Producers as Percent of World Total** | **81** | **80** | **82** | **80** | **80** |

| MANGANESE | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| USSR | 7576 | 6841 | 8459 | 9750 | 10400 |
| South Africa | 1567 | 2679 | 5769 | 5695 | 2886 |
| Brazil | 1396 | 1879 | 2156 | 2282 | 2100 |
| Gabon | 1280 | 1453 | 2245 | 2147 | 1857 |
| China | 1000 | 1000 | 1000 | 1600 | 1600 |
| Australia | 102 | 751 | 1555 | 1999 | 1353 |
| *India* | *1647* | *1651* | *1576* | *1692* | *1320* |
| Mexico | 131 | 274 | 428 | 447 | 350 |
| Ghana | 604 | 405 | 409 | 250 | 190 |
| Hungary | 213 | 169 | 182 | 83 | 85 |
| Japan | 303 | 270 | 158 | 80 | 77 |
| Morocco | 340 | 112 | 131 | 131 | 74 |
| Zaire | 378 | 347 | 309 | 6 | X |
| **World Total** | **17743** | **18222** | **24656** | **26396** | **22443** |
| **Major Producers as Percent of World Total** | **93** | **98** | **99** | **99** | **99** |

| NICKEL | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| USSR | 85 | 110 | 152 | 154 | 170 |
| Canada | 242 | 277 | 242 | 185 | 122 |
| Australia | 0 | 30 | 76 | 74 | 90 |
| New Caledonia | 31 | 105 | 133 | 87 | 63 |
| Indonesia | 4 | 16 | 15 | 53 | 47 |
| Cuba | X | 35 | 37 | 37 | 37 |
| South Africa | 3 | 12 | 21 | 26 | 21 |
| Dominican Rep | 0 | X | 27 | 16 | 20 |
| Philippines | 0 | 0 | 9 | 48 | 19 |
| Botswana | 0 | X | 6 | 15 | 18 |
| Greece | 0 | 10 | 28 | 15 | 16 |
| Brazil | 1 | 3 | 3 | 4 | 11 |
| Zimbabwe | 0 | 11 | 10 | 15 | 10 |
| Finland | 3 | 5 | 5 | 7 | 5 |
| United States | 12 | 14 | 15 | 13 | X |
| **World Total** | **426** | **628** | **808** | **780** | **689** |
| **Major Producers as Percent of World Total** | **90** | **100** | **96** | **96** | **94** |

| TIN | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Malaysia | 64 | 73 | 64 | 61 | 42 |
| USSR | 23 | 27 | 30 | 36 | 37 |
| Indonesia | 15 | 19 | 25 | 33 | 27 |
| Bolivia | 23 | 29 | 24 | 22 | 24 |
| Thailand | 19 | 21 | 16 | 34 | 20 |
| *China* | 25 | 20 | 22 | 15 | 15 |
| Brazil | 2 | 4 | 5 | 7 | 12 |
| Australia | 4 | 9 | 10 | 12 | 10 |
| United Kingdom | 1 | 2 | 3 | 3 | 4 |
| Zaire | 6 | 6 | 5 | 3 | 3 |
| Nigeria | 10 | 8 | 5 | 3 | 2 |
| **World Total** | **204** | **232** | **222** | **247** | **212** |
| **Major Producers as Percent of World Total** | **95** | **94** | **94** | **92** | **93** |

| ZINC | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Canada | 826 | 1239 | 1229 | 1059 | 1070 |
| USSR | 470 | 610 | 690 | 785 | 805 |
| Australia | 355 | 487 | 501 | 495 | 695 |
| Peru | 254 | 299 | 385 | 488 | 553 |
| United States | 554 | 485 | 426 | 317 | 275 |
| Mexico | 225 | 266 | 289 | 236 | 257 |
| Japan | 221 | 280 | 254 | 238 | 256 |
| Sweden | 79 | 93 | 111 | 167 | 203 |
| Ireland | 1 | 97 | 67 | 229 | 186 |
| Spain | 39 | 98 | 84 | 183 | 175 |
| Poland | 152 | 187 | 210 | 188 | 146 |
| Korea, Dem People's Rep | 105 | 130 | 160 | 140 | 140 |
| Germany, Fed Rep | 108 | 129 | 116 | 121 | 114 |
| Zaire | 119 | 105 | 80 | 67 | 75 |
| Italy | 116 | 111 | 76 | 58 | 43 |
| **World Total** | **4308** | **5464** | **5852** | **5962** | **6246** |
| **Major Producers as Percent of World Total** | **84** | **84** | **80** | **80** | **80** |

*(continued on next page.)*

# Table 8.4 CONTINUED

| | Annual Production (thousand metric tons) | | | | |
|---|---|---|---|---|---|
| | 1965 | 1970 | 1975 | 1980 | 1983 |
| **PHOSPHATE ROCK** | | | | | |
| United States | 26746 | 35143 | 44276 | 54415 | 42573 |
| USSR | 13600 | 20800 | 24150 | 25300 | 27000 |
| Morocco | 9824 | 11400 | 13548 | 18824 | 20106 |
| China | 900 | 1700 | 3400 | 10726 | 12500 |
| Tunisia | 3040 | 3016 | 3481 | 4582 | 5924 |
| Jordan | 828 | 841 | 1353 | 3911 | 4749 |
| Brazil | 279 | 173 | 406 | 2612 | 3208 |
| Israel | 388 | 1162 | 882 | 2307 | 2969 |
| South Africa | 610 | 1685 | 1646 | 3185 | 2742 |
| Togo | 969 | 1508 | 1161 | 2933 | 2081 |
| Nauru | 1496 | 2114 | 2050 | 2087 | 1684 |
| Senegal | 1002 | 1128 | 1883 | 1632 | 1249 |
| Christmas Island | 857 | 1089 | 1391 | 1713 | 1094 |
| Vietnam | 1050 | 455 | 1400 | 90 | 220 |
| Western Sahara | 0 | 0 | 2682 | X | X |
| **World Total** | **63776** | **87126** | **107678** | **139214** | **135000** |
| **Major Producers as Percent of World Total** | **97** | **94** | **96** | **96** | **95** |
| **POTASH** | | | | | |
| USSR | 2368 | 4087 | 7944 | 8064 | 9300 |
| Canada | 1353 | 3103 | 5436 | 7532 | 6203 |
| German Dem Rep | 1926 | 2419 | 3019 | 3422 | 3430 |
| Germany, Fed Rep | 2384 | 2645 | 2223 | 2737 | 2100 |
| France | 1888 | 1904 | 1920 | 1894 | 1900 |
| United States | 2848 | 2476 | 2269 | 2239 | 1429 |
| Israel | 293 | 554 | 696 | 797 | 1000 |
| Spain | 405 | 521 | 567 | 658 | 657 |
| United Kingdom | 0 | 0 | 0 | 321 | 302 |
| Jordan | 0 | 0 | 0 | X | 170 |
| Italy | 318 | 365 | 282 | 156 | 140 |
| Chile | X | X | X | 25 | 22 |
| China | X | X | 300 | 12 | 20 |
| **World Total** | **13724** | **18155** | **24740** | **27857** | **26678** |
| **Major Producers as Percent of World Total** | **100** | **100** | **100** | **100** | **100** |
| **SULFUR** | | | | | |
| USSR | 1430 | 1600 | 7980 | 9590 | 9590 |
| United States | 7449 | 8676 | 11439 | 11866 | 9290 |
| Canada | 1876 | 4439 | 7536 | 7260 | 6625 |
| Poland | 431 | 2683 | 5081 | 5535 | 5240 |
| Japan | 250 | 342 | 2489 | 2784 | 2645 |
| China | 250 | 250 | 1070 | 2200 | 2600 |
| France | 1521 | 1735 | 1993 | 2216 | 2063 |
| Mexico | 1586 | 1381 | 2216 | 2217 | 1633 |
| Germany, Fed Rep | 77 | 176 | 1282 | 1799 | 1540 |
| Spain | 43 | 6 | 1371 | 1236 | 1131 |
| Italy | 16 | 143 | 703 | 604 | 458 |
| German Dem Rep | 125 | 109 | 365 | 360 | 360 |
| Iran | 32 | 414 | 495 | 220 | 65 |
| **World Total** | **15531** | **22518** | **50190** | **54920** | **50472** |
| **Major Producers as Percent of World Total** | **97** | **97** | **88** | **87** | **86** |

| | Annual Production (thousand metric tons) | | | | |
|---|---|---|---|---|---|
| | 1965 | 1970 | 1975 | 1980 | 1983 |
| **ALUMINUM** | | | | | |
| United States | 2499 | 3607 | 3519 | 4654 | 3353 |
| USSR | 840 | 1100 | 1530 | 1760 | 2000 |
| Canada | 753 | 972 | 887 | 1068 | 1091 |
| Germany, Fed Rep | 234 | 309 | 678 | 731 | 730 |
| Norway | 279 | 522 | 595 | 653 | 715 |
| Australia | 88 | 206 | 214 | 303 | 475 |
| China | 100 | 130 | 200 | 360 | 380 |
| France | 341 | 381 | 383 | 432 | 361 |
| Spain | 52 | 120 | 210 | 386 | 358 |
| Venezuela | X | 23 | 50 | 328 | 343 |
| Japan | 294 | 733 | 1013 | 1091 | 256 |
| United Kingdom | 36 | 40 | 308 | 374 | 250 |
| Netherlands | X | 75 | 261 | 259 | 235 |
| India | 69 | 161 | 160 | 185 | 205 |
| Italy | 123 | 147 | 190 | 271 | 196 |
| **World Total** | **6318** | **9653** | **12140** | **15371** | **13865** |
| **Major Producers as Percent of World Total** | **90** | **88** | **84** | **84** | **79** |
| **CRUDE STEEL** | | | | | |
| USSR | X | 115886 | 141325 | 147941 | 153000 |
| Japan | X | 93322 | 102313 | 111395 | 97164 |
| United States | X | 119305 | 105816 | 101455 | 76761 |
| China | X | 18000 | 25000 | 37120 | 39952 |
| Germany, Fed Rep | X | 45041 | 40415 | 43838 | 35730 |
| Italy | X | 17277 | 21836 | 26501 | 21674 |
| France | X | 23773 | 21530 | 23176 | 17612 |
| Czechoslovakia | X | 11480 | 14323 | 15225 | 15024 |
| United Kingdom | X | 28316 | 20198 | 11278 | 14993 |
| Brazil | X | 5390 | 8308 | 15339 | 14659 |
| Poland | X | 11795 | 15007 | 19485 | 13600 |
| Canada | X | 11200 | 13025 | 15887 | 12828 |
| Belgium | X | 12607 | 11587 | 12325 | 10155 |
| **World Total** | **X** | **594418** | **643798** | **713788** | **657224** |
| **Major Producers as Percent of World Total** | **X** | **86** | **84** | **81** | **80** |

**Source:** U.S. Bureau of Mines.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 8.5 MAJOR CONSUMERS OF REFINED METALS, 1965–83

| | Consumption of Refined Metals (thousand metric tons per year) | | | | | Metric Tons of Metal Consumed per Million Constant (1975) $US of GNP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1965 | 1970 | 1975 | 1980 | 1983 | 1965 | 1970 | 1975 | 1980 | 1983 |
| **ALUMINUM** | | | | | | | | | | |
| United States | 2852 | 3488 | 3265 | 4454 | 4219 | 2.41 | 2.54 | 2.10 | 2.40 | 2.21 |
| Japan | 286 | 930 | 1171 | 1639 | 1801 | 1.85 | 2.35 | 2.35 | 2.56 | 2.54 |
| Germany, Fed Rep | 387 | 670 | 704 | 1042 | 1085 | 1.99 | 1.76 | 1.67 | 2.08 | 2.16 |
| France | 249 | 413 | 399 | 601 | 613 | 1.48 | 1.48 | 1.18 | 1.50 | 1.49 |
| Italy | 128 | 279 | 270 | 458 | 430 | 1.20 | 1.63 | 1.41 | 1.98 | 1.88 |
| United Kingdom | 364 | 404 | 393 | 409 | 323 | 2.12 | 1.93 | 1.70 | 1.63 | 1.23 |
| Canada | 169 | 223 | 293 | 312 | 295 | 1.95 | 1.76 | 1.82 | 1.68 | 1.57 |
| Belgium | 117 | 175 | 178 | 233 | 272 | 4.05 | 3.31 | 2.81 | 3.22 | 3.79 |
| Spain | 64 | 129 | 217 | 263 | 217 | 1.62 | 1.62 | 2.07 | 2.29 | 1.83 |
| 9 OECD Countries | 4615 | 6712 | 6890 | 9411 | 9256 | 2.16 | 2.19 | 1.93 | 2.21 | 2.10 |
| USSR | 1000 | 1281 | 1580 | 1850 | 1850 | X | X | X | X | X |
| China | 95 | 180 | 300 | 550 | 620 | X | 1.52 | 1.94 | 2.65 | 2.41 |
| Brazil | 52 | 84 | 209 | 296 | 271 | 1.32 | 1.12 | 1.71 | 1.77 | 1.73 |
| German Dem Rep | 140 | 150 | 200 | 230 | 230 | X | X | X | X | X |
| **World Total** | **6699** | **9928** | **11299** | **15285** | **15388** | | | | | |
| **Major Consumers as Percent of World Total** | **88** | **85** | **81** | **81** | **79** | | | | | |
| **COPPER** | | | | | | | | | | |
| United States | 1819 | 1854 | 1397 | 1868 | 1775 | 1.54 | 1.35 | 0.90 | 1.01 | 0.93 |
| Japan | 428 | 821 | 827 | 1158 | 1216 | 2.77 | 2.07 | 1.66 | 1.81 | 1.72 |
| Germany, Fed Rep | 536 | 698 | 635 | 748 | 737 | 2.75 | 1.84 | 1.51 | 1.49 | 1.47 |
| France | 287 | 331 | 365 | 433 | 390 | 1.71 | 1.18 | 1.07 | 1.08 | 0.95 |
| United Kingdom | 650 | 554 | 451 | 409 | 358 | 3.80 | 2.64 | 1.95 | 1.63 | 1.37 |
| Italy | 192 | 274 | 299 | 388 | 325 | 1.79 | 1.60 | 1.56 | 1.68 | 1.42 |
| Belgium | 99 | 145 | 177 | 304 | 258 | 3.42 | 2.75 | 2.81 | 4.20 | 3.60 |
| Canada | 204 | 229 | 196 | 209 | 195 | 2.35 | 1.81 | 1.21 | 1.13 | 1.04 |
| 8 OECD Countries | 4214 | 4905 | 4346 | 5517 | 5255 | 2.01 | 1.64 | 1.26 | 1.33 | 1.23 |
| USSR | 785 | 960 | 1220 | 1300 | 1360 | X | X | X | X | X |
| China | 120 | 200 | 315 | 386 | 428 | X | 1.69 | 2.03 | 1.86 | 1.66 |
| **World Total** | **6115** | **7265** | **7472** | **9361** | **9113** | | | | | |
| **Major Consumers as Percent of World Total** | **84** | **83** | **79** | **77** | **77** | | | | | |
| **LEAD** | | | | | | | | | | |
| United States | 754 | 894 | 820 | 1094 | 1135 | 0.64 | 0.65 | 0.53 | 0.59 | 0.59 |
| Japan | 147 | 211 | 189 | 393 | 360 | 0.95 | 0.53 | 0.38 | 0.61 | 0.51 |
| Germany, Fed Rep | 271 | 309 | 225 | 333 | 318 | 1.39 | 0.81 | 0.53 | 0.66 | 0.63 |
| United Kingdom | 312 | 262 | 238 | 296 | 293 | 1.82 | 1.25 | 1.03 | 1.18 | 1.12 |
| Italy | 94 | 168 | 146 | 275 | 229 | 0.88 | 0.98 | 0.76 | 1.19 | 1.00 |
| France | 145 | 193 | 174 | 213 | 196 | 0.86 | 0.69 | 0.51 | 0.53 | 0.48 |
| Yugoslavia | 43 | 45 | 83 | 128 | 133 | 2.08 | 1.95 | 2.69 | 3.14 | 3.29 |
| Spain | 87 | 78 | 74 | 111 | 101 | 2.20 | 0.97 | 0.70 | 0.96 | 0.86 |
| 8 OECD Countries | 1852 | 2158 | 1948 | 2842 | 2765 | 0.91 | 0.74 | 0.58 | 0.70 | 0.66 |
| USSR | 385 | 486 | 620 | 800 | 805 | X | X | X | X | X |
| China | 100 | 160 | 185 | 210 | 220 | X | 1.35 | 1.19 | 1.01 | 0.85 |
| Bulgaria | X | 77 | 95 | 110 | 117 | X | X | X | X | X |
| German Dem Rep | 80 | 100 | 91 | 100 | 98 | X | X | X | X | X |
| Mexico | 56 | 94 | 72 | 85 | 86 | 1.64 | 1.49 | 0.83 | 0.72 | 0.73 |
| **World Total** | **3194** | **3871** | **3914** | **5348** | **5229** | | | | | |
| **Major Consumers as Percent of World Total** | **77** | **79** | **77** | **78** | **78** | | | | | |
| **NICKEL** | | | | | | | | | | |
| United States | 156 | 141 | 133 | 142 | 139 | 0.13 | 0.10 | 0.09 | 0.08 | 0.07 |
| Japan | 27 | 98 | 90 | 122 | 115 | 0.17 | 0.25 | 0.18 | 0.19 | 0.16 |
| Germany, Fed Rep | 31 | 41 | 43 | 68 | 63 | 0.16 | 0.11 | 0.10 | 0.13 | 0.13 |
| France | 21 | 36 | 32 | 38 | 33 | 0.12 | 0.13 | 0.09 | 0.10 | 0.08 |
| Italy | 9 | 20 | 17 | 27 | 23 | 0.09 | 0.12 | 0.09 | 0.12 | 0.10 |
| United Kingdom | 37 | 35 | 21 | 23 | 22 | 0.22 | 0.17 | 0.09 | 0.09 | 0.08 |
| Sweden | 13 | 23 | 22 | 20 | 16 | 0.35 | 0.36 | 0.30 | 0.26 | 0.21 |
| Finland | 0 | 0 | 1 | 9 | 10 | 0.02 | 0.01 | 0.02 | 0.29 | 0.29 |
| Canada | 8 | 11 | 11 | 10 | 5 | 0.09 | 0.08 | 0.07 | 0.05 | 0.03 |
| Austria | 3 | 6 | 4 | 5 | 4 | 0.21 | 0.18 | 0.11 | 0.12 | 0.09 |
| 10 OECD Countries | 306 | 410 | 374 | 465 | 429 | 0.32 | 0.24 | 0.19 | 0.20 | 0.17 |
| USSR | 110 | 130 | 115 | 132 | 140 | X | X | X | X | X |
| China | X | X | 18 | 18 | 19 | X | X | X | 0.09 | 0.07 |
| India | X | X | 3 | 12 | 13 | X | X | X | 0.11 | 0.11 |
| **World Total** | **428** | **567** | **570** | **715** | **683** | | | | | |
| **Major Consumers as Percent of World Total** | **97** | **95** | **90** | **88** | **88** | | | | | |

*(continued on next page.)*

# Table 8.5 CONTINUED

| | Consumption of Refined Metals (thousand metric tons per year) | | | | | Metric Tons of Metal Consumed per Million Constant (1975) $US of GNP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1965 | 1970 | 1975 | 1980 | 1983 | 1965 | 1970 | 1975 | 1980 | 1983 |
| **TIN** | | | | | | | | | | |
| United States | 63 | 57 | 56 | 56 | 46 | 0.05 | 0.04 | 0.04 | 0.03 | 0.02 |
| Japan | 18 | 29 | 28 | 31 | 30 | 0.12 | 0.07 | 0.06 | 0.05 | 0.04 |
| Germany, Fed Rep | 13 | 15 | 13 | 16 | 14 | 0.07 | 0.04 | 0.03 | 0.03 | 0.03 |
| United Kingdom | 21 | 19 | 14 | 10 | 10 | 0.12 | 0.09 | 0.06 | 0.04 | 0.04 |
| France | 10 | 11 | 10 | 10 | 8 | 0.06 | 0.04 | 0.03 | 0.03 | 0.02 |
| Netherlands | 4 | 6 | 4 | 5 | 5 | 0.09 | 0.07 | 0.04 | 0.05 | 0.05 |
| Italy | 6 | 7 | 8 | 6 | 4 | 0.05 | 0.04 | 0.04 | 0.03 | 0.02 |
| Canada | 5 | 5 | 4 | 5 | 4 | 0.06 | 0.04 | 0.03 | 0.03 | 0.02 |
| Belgium | 3 | 3 | 5 | 3 | 2 | 0.09 | 0.06 | 0.08 | 0.04 | 0.03 |
| 9 OECD Countries | 142 | 150 | 142 | 141 | 123 | 0.07 | 0.05 | 0.04 | 0.03 | 0.03 |
| USSR | 29 | 17 | 23 | 25 | 29 | X | X | X | X | X |
| China | 15 | 13 | 14 | 13 | 13 | X | 0.11 | 0.09 | 0.06 | 0.05 |
| Poland | 3 | 4 | 4 | 3 | 5 | X | X | X | X | X |
| Brazil | 2 | 3 | 3 | 5 | 4 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |
| India | 5 | 5 | 3 | 2 | 2 | 0.06 | 0.07 | 0.03 | 0.02 | 0.02 |
| **World Total** | **227** | **228** | **231** | **235** | **215** | | | | | |
| **Major Consumers as Percent of World Total** | **86** | **84** | **82** | **81** | **82** | | | | | |
| **ZINC** | | | | | | | | | | |
| Japan | 322 | 623 | 547 | 752 | 771 | 2.08 | 1.57 | 1.10 | 1.18 | 1.09 |
| United States | 1221 | 1074 | 839 | 810 | 770 | 1.03 | 0.78 | 0.54 | 0.44 | 0.40 |
| Germany, Fed Rep | 334 | 396 | 297 | 406 | 406 | 1.71 | 1.04 | 0.71 | 0.81 | 0.81 |
| France | 186 | 220 | 223 | 330 | 271 | 1.10 | 0.79 | 0.65 | 0.82 | 0.66 |
| Italy | 116 | 178 | 150 | 236 | 208 | 1.08 | 1.04 | 0.78 | 1.02 | 0.91 |
| United Kingdom | 282 | 278 | 207 | 181 | 181 | 1.65 | 1.33 | 0.89 | 0.72 | 0.69 |
| Belgium | 123 | 128 | 103 | 155 | 166 | 4.26 | 2.42 | 1.63 | 2.14 | 2.31 |
| Canada | 85 | 110 | 150 | 133 | 144 | 0.98 | 0.87 | 0.93 | 0.72 | 0.77 |
| 8 OECD Countries | 2669 | 3007 | 2516 | 3003 | 2916 | 1.27 | 1.01 | 0.73 | 0.73 | 0.68 |
| USSR | 401 | 510 | 900 | 1030 | 1050 | X | X | X | X | X |
| China | 100 | 150 | 220 | 200 | 300 | X | 1.26 | 1.42 | 0.96 | 1.17 |
| Poland | 114 | 129 | 152 | 178 | 143 | X | X | X | X | X |
| **World Total** | **4068** | **4886** | **5028** | **6124** | **6154** | | | | | |
| **Major Consumers as Percent of World Total** | **81** | **78** | **75** | **72** | **72** | | | | | |

**Source:** World Bureau of Metal Statistics (London).
0 = zero or one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 8.1 Production of Commercial Energy, 1970–83

**Source:** U.N. Statistical Office, *Energy Statistics Yearbook, 1982* and *1983*, (United Nations, New York, 1984 and 1985), Table 3.

Energy data are compiled by the U.N. Statistical Office primarily from responses to questionnaires sent to national governments, supplemented by official national statistical publications. Additional data and analysis are provided by OECD, OPEC, ILO, FAO, the International Atomic Energy Agency, the International Sugar Organization, and the U.S. Department of Energy. Where official data are not available, the U.N. Statistical Office prepares estimates based on professional or commercial literature.

All units are petajoules (PJ), which are $10^{15}$ (one quadrillion) joules. One petajoule equals .000948 Quads (quadrillion British Thermal Units) and is equivalent to 163,400 "U.N. standard" barrels of oil, or 34,140 "U.N. standard" metric tons of coal. The heat content of various fuels has been converted to coal-equivalent and then petajoule-equivalent values using country- and year-specific conversion factors. For example, a metric ton of hard coal produced in Argentina has an energy value of 0.843 metric tons of standard coal equivalent (7 million kcal) while a metric ton of hard coal produced in Turkey has an energy value of 0.929 metric tons of coal equivalent. The original national production data for hard coal were multiplied by these conversion factors, and the resulting figures in metric tons of coal-equivalent were multiplied by $29.3076 \times 10^{-6}$ to yield petajoule equivalents. Similarly, other fuels were converted to coal equivalent and petajoule-equivalent terms.

Only commercially traded fuels of the following types are included in the production statistics:

1. Solid fuels include hard coal, lignite, peat, and oil shale burned directly;
2. Liquid fuels include crude petroleum and natural gas liquids;
3. Gaseous fuels include natural gas;
4. Primary electricity includes hydro, geothermal, and nuclear electric power generation expressed as the energy value of the electricity. It is given in gross terms, without deductions for plant use and transmission losses.

Fuelwood, bagasse, charcoal, and new forms of solar energy are excluded from the production figures even when traded commercially.

### Table 8.2 Consumption of Commercial Energy and Total Requirements, 1970–83

**Sources:** Energy data: U.N. Statistical Office, *Energy Statistics Yearbook 1982* and *1983*, (United Nations, New York, 1984 and 1985), Table 3 and Table 4. Population data: U.N. Department of International Economic and Social Affairs, *World Population Prospects: Estimates and Projections As Assessed in 1982* (United Nations, New York, 1985). Gross National Product data: unpublished World Bank data.

A gigajoule (GJ) is one billion ($10^9$) joules. A megajoule (MJ) is one million ($10^6$) joules.

Consumption of commercial energy equals domestic production plus net imports, minus net stock increases, minus aircraft and marine bunkers.

The imports referred to under "Imports as Percentage of Consumption" are net imports, minus stock increases, minus bunkers.

"Total Requirements" is an estimate of the total amount of energy a nation requires in a given year. It differs from total commercial energy consumption by the inclusion of traditional fuels (fuelwood, charcoal, bagasse, animal and vegetable wastes) and by the treatment of primary electricity.

To calculate total requirements, primary electricity is valued on a fossil-fuel avoided basis rather than an energy-output basis. For example, a hydroelectric power plant that produces 1000 kWh of electricity provides the equivalent heat of 0.123 metric tons of coal. However, more than 0.123 metric tons of coal would be required to produce 1000 kWh of electricity. Much of the energy released from coal combustion in a power plant is used in the mechanical work of turning dynamos or lost in waste heat, so less energy is embodied in the final electricity than in the initial coal. The efficiency of a thermal electric plant is the ratio between final electrical energy produced and initial potential energy supplied. Although this rating varies widely from country to country and from plant to plant, the U.N. Statistical Office uses a standard factor of 30 percent efficiency to estimate the fossil fuel value of hydro, geothermal, and nuclear electricity.

Fuelwood and charcoal consumption are estimated from population data and country-specific per-capita consumption figures. These per capita consumption estimates were prepared by the FAO after an assessment of the available consumption data. Specific consumption of non-coniferous fuelwood ranges from .0016 $m^3$ per capita per year in Jordan to .9783 $m^3$ per capita per year in Benin. Similar estimates were prepared for coniferous fuelwood and charcoal. Although the energy value of fuelwood and charcoal varies widely, the U.N. Statistical Office uses standard factors of .33 metric tons of coal equivalent per cubic meter of fuelwood and .986 metric tons of coal equivalent per metric ton of charcoal.

Bagasse production is based on sugar production data in the *Sugar Yearbook* of the International Sugar Organization. It is assumed that 3.26 metric tons of fuel bagasse at 50 percent moisture are produced per metric ton of extracted cane sugar. The energy of a metric ton of bagasse is valued at .264 metric tons of coal equivalent.

### Table 8.3 Nuclear Power and Waste Generation, 1970–84

**Sources:** Reactor and capacity data for 1970 for all countries except USSR: *Nucleonics Week* (January 1971). Reactor and capacity data for 1984 for all countries: U.S. Department of Energy, *Commercial Nuclear Power: Prospects for the United States and the World* (U.S. Department of Energy/Energy Information Administration, Washington, D.C., September 1985). Nuclear electricity generation for 1973: unpublished U.S. Department of Energy data. Total electricity generation for 1973: OECD, *Energy Balances of OECD Countries 1970–82* (Organization for Economic Cooperation and Development/International Energy Agency, Paris, 1984) and OECD, *Energy Balances of Developing Countries 1971–82* (Organization for Economic Cooperation and Development/International Energy Agency, Paris, 1984). Nuclear electricity generation as percent of total for non-market countries for 1983: *Nuclear Engineering International*, Vol. 29, p. 3 (October 1984). Data for USSR reactors, capacity, and nuclear electricity generation as percent of total for 1970: W. P. Geddes, "Uranium and Nuclear Power in the Soviet Bloc," (unpublished monograph, November 1984). Spent fuel inventory data: U.S. Department of Energy, *World Nuclear Fuel Cycle Requirements* (U.S. Department of Energy/Energy Information Administration, Washington, D.C., November 1985).

A gigawatt of electricity (GWe) is one billion ($10^9$) watts of electric power.

All data are for December 31 of the year indicated.

Number of reactors refers to those power reactors that have produced electricity into the electrical grid, although not necessarily at full power. Reactors in extended shutdown are included. Reactors under construction or which have been decommissioned are excluded.

Installed capacity is on a net basis. Electric requirements of the generating plant, usually about 5 to 10 percent of gross generation, have been deducted.

Nuclear electricity generation as percent of total is the total electricity generated into grids by nuclear power plants divided by electricity generation from all sources.

Spent fuel inventories are expressed as cumulative totals to the years given and are net of reprocessing. "Heavy metal" refers to the actinide elements (uranium, plutonium, etc.) contained in the spent fuel.

### Table 8.4 Production of Selected Materials, 1965–83

**Source:** U.S. Bureau of Mines, *Minerals Yearbook* (U.S. Government Printing Office, Washington, D.C., 1967, 1977, and 1983).

Production refers to the amount of material mined or refined in the given year.

Potash refers to marketable potash.

Sulfur refers to elemental sulfur.

Aluminum refers to primary aluminum.

Crude steel refers to steel ingots and castings.

Production figures for the ten ores refer to the metal content of mine output. However, common definitions are not always used, making inter-country and inter-year comparisons difficult. In 1983, for example, Brazil's manganese production was qualified as "manganese ore and concentrate, marketable, gross weight, direct sales and beneficiated", while Morocco's production figures were for "manganese ore, largely chemical grade". In 1965, South Africa's manganese production is reported for "manganese, ore and concentrate, gross weight, chemical and metallurgical". Gabon's manganese production data for 1965 are for "ore, 50–53 percent manganese", as well as "battery and chemical grade pellets, 82–84 percent manganese". Similar problems exist with the data for other materials; refer to the source for specific definitions and qualifications.

The countries listed represent the top ten producers of each material for the five years in the table. Since two or three countries may have moved into and out of the top ten grouping over the 18-year period, more than ten countries are listed for some materials. Countries are listed in descending order of 1983 production.

Some of the data for 1983 are estimates. See source for details.

## Table 8.5 Major Consumers of Refined Metals, 1965–83

**Sources:** Metal consumption: *World Metal Statistics,* (World Bureau of Metal Statistics, London, April 1970, December 1974, February 1979, and June 1985). GNP for 1970–83: unpublished World Bank data. GNP for 1965: World Bank, *World Tables* (The Johns Hopkins University Press, Baltimore, Maryland, 1983).

The World Bureau of Metal Statistics publishes consumption data for the six metals presented as well as occasional consumption data for antimony and cadmium. These data are compiled from metal companies, government agencies, trade groups, and statistical bureaus. Obviously incorrect data are revised, but most data are compiled and reported without adjustment or restrospective revisions.

Consumption of refined metals is determined on the basis of first use after refinement. Metal that is melted and recycled is not counted as new consumption; scrap that is refined is treated as new consumption. The metal used in a product that is then exported is considered to be consumed by the producing country rather than by the importing country.

The countries listed represent the ten largest consumers of each metal for the five years in the table. Since two or three countries may have moved into and out of the top ten grouping over the 18-year period, more than ten countries are listed for some metals. Countries are listed within groupings in descending order of their 1983 consumption.

The world total refers to the aggregate consumption of all countries, not only those listed. Major consumers refers to the 10 to 15 countries listed. Major OECD consumers refers to the listed members of the Organization for Economic Cooperation and Development, including Yugoslavia.

Copper data for China for all years includes, in addition to the People's Republic, the centrally planned Asian countries of Viet Nam, Democratic People's Republic of Korea, Democratic Kampuchea, and Lao People's Democratic Republic. The consumption of these countries is assumed to be minor in comparison to that of China.

# 9. Freshwater

The demand for freshwater has increased with the rapid growth of population, agriculture, and industry, and as a result formerly abundant supplies of clean water have been depleted or polluted. The basic unit of concern in dealing with freshwater is the watershed or river basin, defined as the catchment area from which the waters of a river or river system flow. Human activities that modify the natural flow of water and sediments—building dams, cutting down forests, causing excessive soil erosion, discharging pollutants—have impacts throughout the watershed. In most large river basins (see Table 9.3) these impacts are imposed on people living in other regions or in other countries, and this can lead to serious conflicts.

Ideally, comparable and timely statistics on water resources, water quality, and floods should be available for river basins as well as for countries. But because of data limitations, the statistics in this chapter highlight conditions and trends for countries only.

A country's water resources can be compared with others in terms of per capita availability. (See Table 9.1.) A supply of 1,000 cubic meters or less per capita per annum is considered very low; 1,000–5,000 is low; 5,000–10,000 is medium; and 10,000 and above is high. Of the 98 countries for which data are available, 14 are rated very low; 36 are rated low; 14 are rated medium; and 34 are rated high.

Availability statistics include water from both internal and transit sources. For example, Hungary has an estimated 120 cubic kilometers of water potentially available for use: 6 from internal stable runoff and 114 from imports, mostly from the Danube. Clearly, however, not all this water is available for withdrawal because most of it flows to other countries downstream.

In water-rich countries, per-capita withdrawals are a small fraction of available supplies. A country may be reaching a critical level of exploitation if it uses (withdraws) one third or more of its available supplies in an average year. Nineteen of the 98 countries are in this situation. In arid and semi-arid countries such as Sudan, Yemen, Israel, Saudi Arabia, and Libya, available supplies are almost fully utilized.

Freshwater quality can be measured in terms of pollutant discharges, ambient concentrations, and impacts on human health and on natural systems. Table 9.2 presents information on ambient levels of pollution in major rivers as reported to the Organization for Economic Co-operation and Development (OECD).

One measure of water quality is the amount of dissolved oxygen (DO), which indicates the extent to which freshwater can support aquatic life. Depending on temperature, water with less than 5 milligrams of DO per liter is considered of poor quality. The data indicate that DO in many rivers in OECD countries has increased in the last decade because the amount of biodegradable waste discharged into streams has been reduced.

Water authorities try to maintain average phosphorous concentrations below 0.1 milligrams per liter of water, to limit excessive algal growth and the process of eutrophication. By this measure a few countries have improved, but most have not achieved the recommended level. Nitrates are found in increasing concentrations in many OECD countries' rivers because of increased fertilizer use and other causes.

Lead, cadmium, chromium, copper, and other metals have caused water quality problems in OECD countries. Most often these are hot spots where a small stretch of river is seriously polluted and the use of the water (or fish from the river) is curtailed or prohibited. Levels of cadmium above 5 micrograms per liter and lead above 50 micrograms per liter can make water supplies unsafe for human and animal consumption. However, almost all annual average data fall considerably below these guidelines.

Between 1964 and 1982, floods killed 80,000 people and affected 221 million more. Floods and cyclones are causing increasing damage and death tolls because more and more houses and businesses are being built on low-lying flood plains and in the path of tropical storms. (See Table 9.4.) Rapid population growth and an inequitable distribution of land in some countries force many more people to live in hazardous zones. Compounding the problem is excessive sediment from erosion upstream (caused largely by deforestation) that settles in river channels, leaving less capacity for storm runoff.

# Table 9.1 FRESHWATER, AVAILABILITY AND USE, 1970s

| | | Availability | | Withdrawal | | Sectoral Use (percent) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year of Information | Total (cubic kilometers per year) | Per Capita (thousand cubic meters per year) | Total (cubic kilometers per year) | Per Capita (thousand cubic meters per year) | Public | Industry (self-supplied) | Electricity Generation Facilities (cooling) | Agriculture (irrigation) |
| **WORLD** | | | | | | | | | |
| **AFRICA** | | | | | | | | | |
| Algeria | 1970 | 25.00 | 1.82 | 2.00 | 0.15 | 13 | 6 | 0 | 81 |
| Angola | X | X | X | X | X | X | X | X | X |
| Benin | 1970 | 26.00 | 9.60 | X | X | X | X | X | X |
| Botswana | X | X | X | X | X | X | X | X | X |
| Burkina Faso | X | X | X | X | X | X | X | X | X |
| Burundi | X | X | X | X | X | X | X | X | X |
| Cameroon | X | 208.00 | 27.43 | X | X | X | X | X | X |
| Cape Verde | X | X | X | X | X | X | X | X | X |
| Central African Rep | X | X | X | X | X | X | X | X | X |
| Chad | X | X | X | X | X | X | X | X | X |
| Comoros | X | X | X | X | X | X | X | X | X |
| Congo | X | X | X | X | X | X | X | X | X |
| Djibouti | 1973 | X | X | 0.01 | 0.03 | X | X | X | X |
| Egypt | 1976 | 56.00 | 1.47 | 45.00 | 1.18 | 1 | 0 | 0 | 98 |
| Equatorial Guinea | X | X | X | X | X | X | X | X | X |
| Ethiopia | X | 110.00 | 3.79 | X | X | X | X | X | X |
| Gabon | X | X | X | X | X | X | X | X | X |
| Gambia | X | X | X | X | X | X | X | X | X |
| Ghana | 1970 | 53.00 | 6.15 | 0.30 | 0.03 | 44 | 3 | 0 | 54 |
| Guinea | X | X | X | X | X | X | X | X | X |
| Guinea-Bissau | X | X | X | X | X | X | X | X | X |
| Ivory Coast | X | 74.00 | 10.94 | X | X | X | X | X | X |
| Kenya | X | 14.80 | 1.08 | X | X | X | X | X | X |
| Lesotho | X | X | X | X | X | X | X | X | X |
| Liberia | X | X | X | X | X | X | X | X | X |
| Libya | 1977-78 | 0.70 | 0.26 | 1.47 | 0.55 | 17 | 0 | 0 | 83 |
| Madagascar | X | 40.00 | 5.26 | X | X | X | X | X | X |
| Malawi | X | X | X | X | X | X | X | X | X |
| Mali | X | X | X | X | X | X | X | X | X |
| Mauritania | 1978 | X | X | 0.73 | 0.47 | 2 | 0 | 0 | 98 |
| Mauritius | 1974 | 2.20 | 2.53 | 0.36 | 0.41 | X | X | X | X |
| Morocco | 1972 | 25.00 | 1.63 | 8.00 | 0.52 | 4 | 3 | 0 | 94 |
| Mozambique | X | X | X | X | X | X | X | X | X |
| Niger | X | X | X | X | X | X | X | X | X |
| Nigeria | X | X | X | X | X | X | X | X | X |
| Rwanda | X | X | X | X | X | X | X | X | X |
| Senegal | X | X | X | X | X | X | X | X | X |
| Sierra Leone | X | X | X | X | X | X | X | X | X |
| Somalia | X | X | X | X | X | X | X | X | X |
| South Africa | 1970 | 50.00 | 2.20 | 9.20 | 0.40 | 17 | 0 | 0 | 83 |
| Sudan | 1970 | 18.50 | 1.33 | 18.15 | 1.31 | 2 | 0 | 0 | 98 |
| Swaziland | X | X | X | X | X | X | X | X | X |
| Tanzania, United Rep | 1970 | X | X | 0.48 | 0.04 | 38 | 0 | 0 | 63 |
| Togo | X | 11.50 | 5.11 | 0.05 | 0.02 | 90 | 0 | 0 | 10 |
| Tunisia | 1977 | 3.35 | 0.57 | 1.07 | 0.18 | 19 | 5 | 0 | 77 |
| Uganda | 1970 | X | X | 0.20 | 0.02 | 43 | 0 | 0 | 57 |
| Zaire | X | X | X | X | X | X | X | X | X |
| Zambia | 1970 | X | X | 0.36 | 0.09 | 72 | 0 | 0 | 28 |
| Zimbabwe | X | X | X | X | X | X | X | X | X |
| **NORTH AMERICA** | | | | | | | | | |
| Barbados | 1962 | 0.05 | 0.23 | 0.03 | 0.12 | 45 | 35 | 0 | 20 |
| *Canada* | *1977* | *3122.00* | *134.24* | *30.00* | *1.29* | *13* | *39* | *39* | *10* |
| Costa Rica | 1970 | 95.00 | 54.85 | 1.35 | 0.78 | 0 | 8 | 0 | 92 |
| Cuba | 1975 | 34.50 | 3.70 | 8.10 | 0.87 | 14 | 4 | 0 | 83 |
| Dominican Rep | 1975 | 20.00 | 4.04 | X | X | X | X | X | X |
| El Salvador | 1975 | 18.95 | 4.57 | 1.00 | 0.24 | 17 | 0 | 0 | 83 |
| Guatemala | 1970 | 116.00 | 21.67 | 0.73 | 0.14 | 0 | 18 | 0 | 82 |
| Haiti | X | 11.00 | 2.13 | X | X | X | X | X | X |
| Honduras | 1970 | 102.00 | 38.65 | 1.34 | 0.51 | 0 | 4 | 0 | 96 |
| Jamaica | 1975 | 8.30 | 4.06 | 0.32 | 0.16 | 3 | 6 | 0 | 91 |
| Mexico | 1975 | 357.40 | 5.94 | 54.20 | 0.90 | 5 | 7 | 0 | 88 |
| Nicaragua | 1975 | 175.00 | 72.67 | 0.89 | 0.37 | 18 | 45 | 0 | 37 |
| Panama | 1975 | 144.00 | 82.38 | 1.30 | 0.74 | 12 | 11 | 0 | 77 |
| Trinidad and Tobago | 1975 | X | X | 0.15 | 0.14 | 0 | 50 | 0 | 50 |
| United States | 1975 | 2478.00 | 11.47 | 472.00 | 2.19 | 10 | 11 | 38 | 41 |
| **SOUTH AMERICA** | | | | | | | | | |
| Argentina | 1976 | 694.00 | 26.64 | 27.60 | 1.06 | 9 | 8 | 10 | 73 |
| Bolivia | 1959 | X | X | X | X | 1 | 1 | 0 | 97 |
| Brazil | X | 5190.00 | 48.04 | X | X | X | X | X | X |
| Chile | 1975 | X | X | 16.80 | 1.65 | 5 | 4 | 0 | 92 |
| Colombia | 1960 | 1070.00 | 68.86 | X | X | 14 | 0 | 0 | 86 |
| Ecuador | 1973 | 314.00 | 45.57 | X | X | X | X | X | X |
| Guyana | 1971 | X | X | 5.40 | 7.62 | 1 | 0 | 0 | 99 |
| Paraguay | X | X | X | X | X | X | X | X | X |
| Peru | 1975 | 40.00 | 2.64 | X | X | 7 | 0 | 0 | 93 |
| Suriname | X | X | X | X | X | X | X | X | X |
| Uruguay | 1965 | X | X | 0.65 | 0.24 | 15 | 8 | 0 | 77 |
| Venezuela | 1970 | 856.00 | 78.09 | 4.10 | 0.37 | 37 | 4 | 0 | 59 |

# Table 9.1

| | Year of Information | Availability: Total (cubic kilometers per year) | Availability: Per Capita (thousand cubic meters per year) | Withdrawal: Total (cubic kilometers per year) | Withdrawal: Per Capita (thousand cubic meters per year) | Sectoral Use (percent): Public | Sectoral Use (percent): Industry (self-supplied) | Sectoral Use (percent): Electricity Generation Facilities (cooling) | Sectoral Use (percent): Agriculture (irrigation) |
|---|---|---|---|---|---|---|---|---|---|
| **ASIA** | | | | | | | | | |
| Afghanistan | 1970 | 50.00 | 4.01 | X | X | X | X | X | X |
| Bahrain | 1975 | 0.00 | 0.00 | 0.20 | 0.74 | 10 | 6 | 0 | 84 |
| Bangladesh | X | 1357.00 | 17.72 | X | X | X | X | X | X |
| Bhutan | X | X | X | X | X | X | X | X | X |
| Burma | 1970 | 1082.00 | 39.57 | X | X | X | X | X | X |
| China | 1970 | 2680.00 | 3.23 | X | X | X | X | X | X |
| Cyprus | 1972 | 1.00 | 1.63 | 0.55 | 0.89 | 5 | 2 | 0 | 93 |
| India | 1975 | 1850.00 | 2.99 | 380.00 | 0.61 | 3 | 1 | 3 | 93 |
| Indonesia | 1978 | 2530.00 | 17.45 | X | X | 95 | 5 | 0 | 0 |
| Iran | 1975 | 117.50 | 3.52 | 45.40 | 1.36 | 3 | 0 | 0 | 97 |
| Iraq | 1969 | 84.50 | 9.03 | 42.30 | 4.52 | 1 | 5 | 0 | 93 |
| Israel | 1975 | 1.65 | 0.48 | 1.72 | 0.50 | 17 | 6 | 0 | 77 |
| Japan | 1975 | 547.00 | 4.90 | 117.90 | 1.06 | 17 | 33 | 0 | 50 |
| Jordan | 1975 | 0.85 | 0.33 | 0.38 | 0.15 | 1 | 2 | 0 | 97 |
| Kampuchea, Dem | 1970 | 88.10 | 12.70 | X | X | X | X | X | X |
| Korea, Dem People's Rep | X | X | X | X | X | X | X | X | X |
| Korea, Rep | 1976 | 63.00 | 1.23 | 10.70 | 0.21 | 11 | 13 | 0 | 75 |
| Kuwait | 1974 | 0.00 | 0.00 | 0.13 | 0.13 | 35 | 4 | 0 | 61 |
| Lao People's Dem Rep | X | 270.00 | 78.76 | X | X | X | X | X | X |
| Lebanon | 1975 | 4.30 | 1.55 | 0.75 | 0.27 | 13 | 0 | 0 | 87 |
| Malaysia | 1975 | 456.00 | 37.05 | 9.42 | 0.77 | X | X | X | X |
| Mongolia | X | 24.60 | 17.04 | X | X | X | X | X | X |
| Nepal | 1970 | 170.00 | 14.80 | X | X | X | X | X | X |
| Oman | 1975 | 0.66 | 0.86 | 0.43 | 0.56 | 2 | 0 | 0 | 98 |
| Pakistan | 1975 | 298.00 | 3.96 | 153.40 | 2.04 | X | X | X | X |
| Philippines | 1975 | 323.00 | 7.59 | 29.50 | 0.69 | X | X | X | X |
| Qatar | 1975 | 0.02 | 0.13 | 0.04 | 0.23 | 33 | 0 | 0 | 67 |
| Saudi Arabia | 1975 | 2.20 | 0.30 | 2.33 | 0.32 | 36 | 6 | 0 | 58 |
| Singapore | 1975 | 0.60 | 0.27 | 0.19 | 0.08 | X | X | X | X |
| Sri Lanka | 1970 | 43.20 | 3.45 | 6.30 | 0.50 | 0 | 2 | 0 | 98 |
| Syrian Arab Rep | 1976 | 35.30 | 4.75 | 7.00 | 0.94 | 6 | 0 | 0 | 94 |
| Thailand | 1975 | 110.00 | 2.66 | X | X | 1 | 0 | 0 | 99 |
| Turkey | 1970 | 167.00 | 4.73 | 11.80 | 0.33 | 7 | 2 | 7 | 85 |
| United Arab Emirates | 1975 | 0.22 | 0.43 | 0.36 | 0.71 | 9 | 0 | 0 | 91 |
| Viet Nam | X | X | X | X | X | X | X | X | X |
| Yemen | X | X | X | X | X | X | X | X | X |
| Yemen, Dem | 1975 | 1.50 | 0.91 | 1.93 | 1.17 | 1 | 0 | 0 | 99 |
| **EUROPE** | | | | | | | | | |
| Albania | 1967 | 27.50 | 14.71 | 0.20 | 0.11 | 1 | 1 | 98 | 0 |
| Austria | 1975 | 90.00 | 11.97 | 2.75 | 0.37 | 31 | 69 | 0 | 0 |
| Belgium | 1971 | 12.50 | 1.30 | 8.26 | 0.86 | 6 | 37 | 47 | 10 |
| Bulgaria | 1971 | 197.00 | 23.14 | X | X | 33 | 67 | 0 | 0 |
| Czechoslovakia | 1975 | 90.00 | 6.08 | 5.02 | 0.34 | 24 | 72 | 0 | 5 |
| Denmark | 1970 | 12.90 | 2.62 | 0.77 | 0.16 | 43 | 38 | 1 | 18 |
| Finland | 1972 | 104.00 | 22.58 | 4.61 | 1.00 | 7 | 85 | 0 | 8 |
| France | 1975 | 180.00 | 3.42 | 27.00 | 0.51 | 16 | 20 | 44 | 19 |
| German Dem Rep | 1975 | 26.20 | 1.55 | 8.30 | 0.49 | 10 | 77 | 0 | 13 |
| Germany, Fed Rep | 1975 | 160.00 | 2.59 | 33.20 | 0.54 | 10 | 35 | 55 | 0 |
| Greece | 1975 | 55.00 | 6.08 | 4.28 | 0.47 | 14 | 2 | 1 | 84 |
| Hungary | 1972 | 120.00 | 11.59 | 5.60 | 0.54 | 9 | 34 | 9 | 48 |
| Ireland | 1972 | 43.70 | 14.79 | 1.68 | 0.57 | 11 | 14 | 69 | 6 |
| Italy | 1970 | 167.00 | 3.12 | 36.00 | 0.67 | 19 | 4 | 5 | 71 |
| Luxembourg | 1973 | 3.36 | 9.28 | 0.06 | 0.17 | 47 | 50 | 0 | 3 |
| Malta | 1977 | 0.03 | 0.07 | 0.02 | 0.06 | X | X | X | X |
| Netherlands | 1972 | 90.50 | 6.94 | 14.41 | 1.11 | 5 | 24 | 40 | 32 |
| Norway | 1972 | 383.00 | 98.79 | 1.40 | 0.36 | 14 | 84 | 0 | 2 |
| Poland | 1976 | 58.80 | 1.73 | 15.90 | 0.47 | 14 | 21 | 40 | 25 |
| Portugal | 1977 | 87.50 | 9.11 | 6.46 | 0.67 | 7 | 38 | 0 | 55 |
| Romania | 1971 | 192.00 | 9.43 | X | X | 15 | 85 | 0 | 0 |
| Spain | 1975 | 110.00 | 3.09 | 25.00 | 0.70 | 7 | 5 | 17 | 72 |
| Sweden | 1975 | 183.00 | 22.34 | 5.00 | 0.61 | 50 | 50 | 0 | 0 |
| Switzerland | 1973 | 50.00 | 7.81 | 2.50 | 0.39 | 44 | 48 | 0 | 8 |
| United Kingdom | 1972 | 162.70 | 2.93 | 17.66 | 0.32 | 23 | 41 | 35 | 1 |
| Yugoslavia | 1976 | 244.00 | 11.43 | 8.88 | 0.42 | 16 | 38 | 39 | 7 |
| **USSR** | 1975 | 4714.00 | 18.60 | 226.00 | 0.89 | 8 | 15 | 14 | 63 |
| **OCEANIA** | | | | | | | | | |
| Australia | 1975 | 343.00 | 25.17 | 16.90 | 1.24 | X | X | X | X |
| Fiji | X | X | X | X | X | X | X | X | X |
| New Zealand | 1967-68 | 397.00 | 140.78 | 1.01 | 0.36 | 52 | 11 | 23 | 14 |
| Papua New Guinea | X | X | X | X | X | X | X | X | X |
| Solomon Islands | X | X | X | X | X | X | X | X | X |
| **ANTARCTICA** | | | | | | | | | |

**Source:** Bureau of Geological and Mining Research, National Geological Survey, France.
0 = zero or less than one-half the unit of measure; X = not available.
For additional information, see Sources and Technical Notes.

# Table 9.2 WATER QUALITY, SELECTED RIVERS, 1970–83

| | Dissolved Oxygen (DO) (milligrams per liter) | | | | | Biological Oxygen Demand (BOD) (milligrams per liter) | | | | | Nitrates (milligrams per liter) | | | | | Phosphorus (milligrams per liter) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) |
| Canada | | | | | | | | | | | | | | | | | | | | |
| St. Lawrence | 8.1 | 10.0 | X | X | X | X | X | X | X | X | 0.19 | 0.23 | 0.16 | 0.29 | 0.19 | 0.05 | 0.03 | 0.07 | 0.06 | 0.07 |
| Mackenzie | X | X | X | X | X | X | X | X | X | X | 0.08 | 0.11 | 0.11 | 0.08 | 0.10 | X | 0.02 | 0.01 | 0.01 | 0.01 |
| Fraser | X | X | X | X | X | X | X | X | X | X | 0.05 | 0.30 | 0.06 | 0.12 | 0.08 | 0.00 | 0.11 | X | X | X |
| Nelson | X | X | X | X | X | X | X | X | X | X | 0.04 | 0.40 | 0.06 | 0.09 | 0.06 | X | 0.02 | 0.01 | 0.02 | 0.01 |
| United States | | | | | | | | | | | | | | | | | | | | |
| Delaware-Trenton | 9.6 | 10.8 | 11.9 | 10.3 | 11.1 | 1.9 | 2.0 | 2.2 | 2.6 | 2.8 | a X | 0.88 | 1.08 | X | 0.97 | a X | 0.10 | 0.10 | 0.09 | 0.09 |
| Mississippi-St. Franc. | 8.4 | 8.5 | 8.3 | 8.9 | 8.9 | 2.4 | 2.2 | 1.7 | 1.1 | 1.8 | a X | 0.98 | 1.20 | 1.58 | 1.64 | a X | 0.19 | 0.23 | 0.17 | 0.23 |
| Japan | | | | | | | | | | | | | | | | | | | | |
| Ishikari | 8.7 | 10.7 | 10.6 | 10.6 | 10.5 | 1.7 | 1.4 | 1.4 | 1.5 | 1.4 | 0.36 | X | 0.53 | X | X | X | 0.09 | 0.09 | 0.07 | 0.09 |
| Yodo | 8.3 | 8.9 | 9.0 | 8.2 | 8.0 | 3.6 | 3.2 | 3.8 | 4.2 | 4.1 | X | 0.80 | 0.76 | X | 0.66 | X | 0.19 | 0.22 | 0.16 | 0.18 |
| Australia | | | | | | | | | | | | | | | | | | | | |
| Brisbane Estuary | X | 5.6 | 6.4 | 6.0 | 6.2 | X | 1.6 | 1.0 | 1.2 | 1.2 | X | 0.34 | 0.85 | 1.05 | 0.93 | X | 0.20 | 0.38 | 0.48 | 0.43 |
| New Zealand | | | | | | | | | | | | | | | | | | | | |
| Waikato | X | 9.0 | X | X | X | X | 1.5 | X | X | X | X | 0.20 | X | X | X | X | 0.60 | X | X | X |
| Belgium | | | | | | | | | | | | | | | | | | | | |
| Meuse-Heer | 8.2 | 10.8 | 10.6 | X | 10.7 | 4.4 | 6.6 | 4.2 | X | 4.7 | 1.80 | 7.80 | 2.18 | X | 2.09 | X | 1.23 | 0.22 | X | 0.17 |
| Meuse-Lanaye | 7.7 | 8.9 | 9.5 | X | 9.2 | 12.5 | 4.7 | 3.9 | X | 4.0 | 3.90 | 9.40 | 2.52 | X | 2.50 | X | 1.41 | 0.55 | X | 0.55 |
| Escaut-Bleharies | X | 4.0 | 5.9 | X | 4.7 | X | 24.1 | 10.7 | X | 9.6 | X | 0.77 | 4.17 | X | 3.58 | X | 0.70 | 0.94 | X | 1.03 |
| Escaut-Doel | 6.2 | 1.3 | 1.9 | X | 2.1 | 4.0 | 8.2 | 5.0 | X | 14.0 | 3.00 | 7.35 | 4.17 | X | 3.18 | X | 1.06 | 0.55 | X | 0.63 |
| Denmark | | | | | | | | | | | | | | | | | | | | |
| Gudenaa | X | X | 9.7 | 10.7 | 10.2 | X | X | 3.4 | 4.5 | 4.3 | X | 1.25 | 1.70 | 2.00 | 1.84 | X | 0.30 | 0.16 | 0.18 | 0.13 |
| Skjernaa | X | X | 10.5 | 10.4 | 10.4 | X | X | 7.3 | 8.0 | 8.3 | X | X | 3.00 | 3.18 | 2.92 | X | X | 0.22 | 0.13 | 0.17 |
| Susaa | X | X | X | 8.7 | 9.1 | X | X | X | 2.0 | 2.1 | X | 5.27 | 6.73 | 5.21 | 6.09 | X | 0.66 | 0.26 | 0.34 | 0.30 |
| Finland | | | | | | | | | | | | | | | | | | | | |
| Tornionjoki | 11.9 | 11.9 | 12.0 | X | 11.9 | 1.6 | 1.6 | X | X | 1.7 | X | X | X | X | X | 0.02 | 0.02 | 0.02 | X | 0.03 |
| Kymijoki | 9.5 | 10.8 | 9.9 | X | 10.8 | 3.5 | 2.4 | X | X | 2.5 | X | X | X | X | X | 0.05 | 0.03 | 0.03 | X | 0.03 |
| France | | | | | | | | | | | | | | | | | | | | |
| Loire-Nantes | 10.7 | 11.1 | 11.8 | 12.0 | 11.6 | 6.7 | 4.4 | 6.6 | 6.7 | 6.0 | 1.58 | 1.45 | 1.99 | 1.85 | 2.12 | X | X | X | X | X |
| Seine-Tancerville | X | 3.3 | 4.9 | 5.9 | 5.2 | X | 10.2 | 6.6 | 4.1 | 4.9 | X | 4.18 | 5.35 | 5.24 | 5.18 | X | X | X | X | X |
| Garonne-Bordeaux | 9.7 | 9.9 | 10.1 | 9.9 | 9.9 | 2.2 | 1.5 | 2.3 | 2.3 | 2.1 | 1.15 | 0.93 | 1.83 | 1.67 | 1.73 | X | X | X | X | X |
| Rhine-Selz | 8.2 | 9.2 | 10.9 | 8.6 | 8.9 | X | 4.1 | 4.8 | 3.0 | 3.6 | X | 1.58 | 2.92 | 2.94 | 2.62 | X | X | 0.47 | 0.20 | 0.23 |
| Germany, Fed Rep | | | | | | | | | | | | | | | | | | | | |
| Rhine-Bimmen | 5.6 | 6.5 | 8.4 | 9.1 | 9.0 | 6.1 | 6.9 | 3.6 | 3.5 | 3.6 | 1.82 | 3.12 | 3.80 | 3.88 | 3.67 | 0.52 | 0.75 | 0.48 | 0.59 | 0.51 |
| Italy | | | | | | | | | | | | | | | | | | | | |
| Po | X | X | X | X | X | X | 7.3 | 7.3 | X | 7.2 | X | 1.35 | 1.35 | X | X | X | 0.23 | 0.23 | X | X |
| Netherlands | | | | | | | | | | | | | | | | | | | | |
| Meuse-Keizersveer | 8.6 | 9.4 | 10.0 | 9.7 | 9.8 | 6.2 | 4.2 | 2.3 | 2.0 | 2.3 | 3.07 | 3.69 | 3.72 | 3.70 | 3.62 | 0.41 | 0.57 | 0.50 | 0.42 | 0.42 |
| Meuse-Eijsden | 9.8 | 9.5 | 9.8 | 8.7 | 9.1 | 4.1 | 3.7 | 2.8 | 2.8 | 2.8 | 2.45 | 2.51 | 2.78 | 2.71 | 2.68 | 0.43 | 0.73 | 0.58 | 0.53 | 0.50 |
| Scheur-Maasluis | X | 7.1 | 8.1 | 8.7 | 8.5 | X | 3.3 | 2.2 | 1.5 | 1.9 | X | 3.37 | 3.84 | 3.80 | 3.71 | X | 0.56 | 0.65 | 0.56 | 0.53 |
| Ijssel-Kampen | 6.7 | 6.7 | 8.1 | 8.2 | 8.4 | 5.7 | 6.3 | 3.9 | 2.3 | 2.7 | 2.76 | 3.46 | 4.27 | 4.33 | 4.13 | 0.43 | 0.62 | 0.63 | 0.57 | 0.57 |
| Norway | | | | | | | | | | | | | | | | | | | | |
| Skienselva | X | X | X | 6.0 | X | X | 2.5 | 3.5 | X | X | X | 0.35 | 0.35 | 0.34 | 0.34 | X | 0.01 | 0.01 | 0.01 | 0.01 |
| Portugal | | | | | | | | | | | | | | | | | | | | |
| Tejo | 9.0 | X | 9.0 | X | X | 1.6 | X | 2.5 | X | X | 0.52 | X | 5.60 | X | X | X | X | 2.00 | X | X |
| Spain | | | | | | | | | | | | | | | | | | | | |
| Guadalaviar | X | X | X | X | X | X | 12.3 | 11.8 | X | 8.2 | X | 7.54 | 9.60 | X | 8.05 | X | 0.83 | 0.86 | X | 0.43 |
| Sweden | | | | | | | | | | | | | | | | | | | | |
| Dalalven | X | X | X | X | X | X | X | X | X | X | 0.12 | 0.11 | 0.14 | 0.12 | 0.12 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Switzerland | | | | | | | | | | | | | | | | | | | | |
| Rhine-Village | 11.6 | 11.2 | 10.3 | 10.2 | 10.4 | X | X | X | X | X | X | X | 1.39 | 1.43 | 1.39 | X | 0.07 | 0.17 | 0.13 | 0.16 |
| Aare-Brugg | X | 10.2 | 10.2 | X | 10.4 | X | X | X | X | X | X | 1.32 | 1.43 | 1.38 | 1.33 | X | 0.23 | 0.11 | 0.09 | 0.44 |
| Limmat-Baden | X | X | 9.1 | X | X | X | X | X | X | X | X | X | 0.91 | 0.97 | 0.92 | X | X | 0.13 | 0.10 | 0.12 |
| Rhone-Port du Sceaux | X | 10.7 | 10.9 | X | 11.0 | X | X | X | X | X | X | 0.49 | 0.52 | 0.51 | 0.46 | X | 0.12 | 0.10 | 0.10 | 0.10 |
| United Kingdom | | | | | | | | | | | | | | | | | | | | |
| Thames | X | 10.8 | 9.9 | 9.8 | 9.9 | X | 4.2 | X | X | 4.0 | X | 6.50 | 6.89 | 7.10 | 6.99 | b X | 1.07 | 1.16 | X | 1.11 |
| Severn | X | 10.5 | 10.3 | 11.5 | 10.7 | X | 3.9 | X | X | 3.2 | X | 5.52 | 5.80 | 5.45 | 5.64 | b X | 0.75 | 0.54 | X | 0.58 |
| Clyde | X | 7.7 | 9.4 | 8.4 | 8.5 | X | 7.3 | 5.6 | X | 5.3 | X | 2.66 | 1.85 | 2.15 | 1.94 | b X | 0.69 | 0.50 | X | 0.48 |
| Mersey | X | 5.1 | 6.1 | 6.1 | 6.1 | X | 8.6 | X | X | X | X | 1.84 | 2.29 | 2.19 | 2.19 | X | X | X | X | X |
| Yugoslavia | | | | | | | | | | | | | | | | | | | | |
| Dunav | 9.6 | 9.1 | 9.2 | X | 9.5 | 3.4 | 2.5 | 3.5 | X | 3.7 | X | 1.70 | 5.80 | X | 2.50 | X | X | X | X | X |
| Drava | 8.8 | 7.4 | 10.1 | X | 10.0 | 3.4 | 2.6 | 3.1 | X | 3.1 | 4.60 | 5.20 | 7.70 | X | 6.73 | X | X | X | X | X |

# Table 9.2

| | | Lead (micrograms per liter) | | | | | | Cadmium (micrograms per liter) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) | | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) |
| Canada | | | | | | | | | | | | |
| St. Lawrence | | X | X | 1.00 | 3.00 | 1.33 | | X | X | 1.00 | 1.00 | 1.00 |
| Mackenzie | | 10.00 | 5.00 | 4.00 | 3.00 | 3.67 | | X | 1.00 | 1.00 | 1.00 | 1.00 |
| Fraser | | 10.00 | 2.00 | X | X | X | | X | X | X | X | X |
| Nelson | | X | 4.00 | 4.00 | 7.00 | 5.00 | | X | 1.00 | 1.00 | 1.00 | 1.00 |
| United States | | | | | | | | | | | | |
| Delaware-Trenton | | X | 6.00 | 2.00 | X | 2.00 | | X | 2.00 | 3.50 | X | 2.75 |
| Mississippi-St. Franc. | | X | 2.00 | 2.00 | X | 2.33 | | X | 2.00 | 2.00 | X | 2.00 |
| Japan | | | | | | | | | | | | |
| Ishikari | | 210.00 | 1.00 | 5.00 | X | 8.00 | | X | X | X | X | X |
| Yodo | | X | 1.00 | 0.00 | X | 0.00 | | X | X | X | X | X |
| Australia | | | | | | | | | | | | |
| Brisbane Estuary | c | X | 5.70 | 5.30 | 5.00 | 5.10 | c | X | 2.30 | 2.00 | 2.00 | 2.00 |
| New Zealand | | | | | | | | | | | | |
| Waikato | | X | 10.00 | X | X | X | | X | 1.00 | X | X | X |
| Belgium | | | | | | | | | | | | |
| Meuse-Heer | | X | 1.40 | 4.00 | X | 5.33 | | X | 0.80 | 0.30 | X | 0.83 |
| Meuse-Lanaye | | X | 5.70 | 20.00 | X | 12.00 | | X | 2.60 | 1.20 | X | 1.73 |
| Escaut-Bleharies | | X | 11.00 | 18.00 | X | 15.67 | | X | 1.60 | 2.60 | X | 3.17 |
| Escaut-Doel | | X | 203.50 | 25.00 | X | 38.00 | | X | 1.50 | 5.80 | X | 5.73 |
| Denmark | | | | | | | | | | | | |
| Gudenaa | | X | X | X | X | X | | X | X | 10.00 | 1.00 | 4.00 |
| Skjernaa | | X | X | X | X | X | | X | X | X | 10.00 | X |
| Susaa | | X | X | X | X | X | | X | X | X | 1.00 | X |
| Finland | | | | | | | | | | | | |
| Tornionjoki | c | X | X | 0.06 | 0.27 | 0.78 | c | X | X | 0.01 | 0.02 | 0.04 |
| Kymijoki | c | X | X | 0.28 | 0.37 | 0.55 | c | X | X | 0.01 | 0.02 | 0.04 |
| France | | | | | | | | | | | | |
| Loire-Nantes | e | X | 10.00 | 4.00 | 5.00 | 4.67 | f | X | 10.00 | 1.00 | 2.00 | 1.33 |
| Seine-Tancerville | e | X | 26.00 | 8.00 | 14.00 | 9.67 | f | X | 1.00 | 1.00 | 1.00 | 1.33 |
| Garonne-Bordeaux | e | X | 10.00 | 5.00 | 6.00 | 5.67 | f | X | 10.00 | 1.00 | 3.00 | 1.67 |
| Rhine-Selz | | X | 9.30 | 12.50 | 3.20 | 6.03 | | X | 1.00 | 0.80 | 2.00 | 0.53 |
| Germany, Fed Rep | | | | | | | | | | | | |
| Rhine-Bimmen | | X | 24.00 | 7.00 | 8.00 | 9.67 | | X | 2.40 | 1.30 | 0.40 | 0.73 |
| Italy | | | | | | | | | | | | |
| Po | d | X | 0.40 | 0.55 | X | 0.27 | a | X | X | 0.05 | X | 0.06 |
| Netherlands | | | | | | | | | | | | |
| Meuse-Keizersveer | | X | 12.00 | 12.00 | 6.00 | 7.00 | | X | 0.90 | 1.50 | 0.40 | 0.53 |
| Meuse-Eijsden | | X | 17.00 | 23.00 | 12.00 | 17.00 | | X | 3.10 | 3.40 | 1.40 | 1.77 |
| Scheur-Maasluis | | X | 13.00 | 11.00 | 2.00 | 4.33 | | X | 1.00 | 0.90 | 0.50 | 0.67 |
| Ijssel-Kampen | | X | 17.00 | 9.00 | 5.00 | 5.67 | | X | 1.40 | 1.30 | 0.40 | 0.70 |
| Norway | | | | | | | | | | | | |
| Skienselva | c | X | 1.00 | 1.00 | X | X | c | X | 1.00 | 1.00 | X | X |
| Portugal | | | | | | | | | | | | |
| Tejo | c | X | X | 50.00 | X | X | c | X | X | 10.00 | X | X |
| Spain | | | | | | | | | | | | |
| Guadalaviar | | X | 20.00 | 12.70 | X | 12.00 | | X | X | X | X | X |
| Sweden | | | | | | | | | | | | |
| Dalalven | | X | X | X | X | X | | X | X | X | X | X |
| Switzerland | | | | | | | | | | | | |
| Rhine-Village | | X | 1.60 | 1.40 | 1.10 | 1.60 | | X | 0.08 | 0.14 | 0.05 | 0.09 |
| Aare-Brugg | | X | X | X | X | X | | X | X | X | X | X |
| Limmat-Baden | | X | X | X | X | X | | X | X | X | X | X |
| Rhone-Port du Sceaux | | X | X | 3.38 | 2.13 | 2.68 | | X | X | X | X | X |
| United Kingdom | | | | | | | | | | | | |
| Thames | | X | X | X | X | X | | X | X | X | X | X |
| Severn | | X | X | X | X | X | | X | X | X | X | X |
| Clyde | | X | X | X | X | X | | X | X | X | X | X |
| Mersey | | X | X | X | X | X | | X | X | X | X | X |
| Yugoslavia | | | | | | | | | | | | |
| Dunav | | X | 4.41 | 29.98 | X | 33.73 | | X | 0.21 | 6.00 | X | 6.36 |
| Drava | | X | X | X | X | X | | X | X | X | X | X |

| | | Chromium (micrograms per liter) | | | | | | Copper (micrograms per liter) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) | | 1970 | 1975 | 1980 | 1983 | Latest Three Years of Data (average) |
| Canada | | | | | | | | | | | | |
| St. Lawrence | | 0.00 | 0.00 | X | X | X | | 0.01 | 0.01 | 14.00 | 17.00 | 13.67 |
| Mackenzie | c | X | 0.01 | X | X | X | | 10.00 | 7.00 | 2.00 | 14.00 | 9.33 |
| Fraser | | X | X | X | X | X | | 10.00 | 4.00 | X | X | X |
| Nelson | | X | X | X | X | X | | X | 4.00 | 5.00 | 16.00 | 7.67 |
| United States | | | | | | | | | | | | |
| Delaware-Trenton | d | X | 27.50 | 10.00 | X | 10.00 | d | X | 20.00 | 3.50 | X | 3.50 |
| Mississippi-St. Franc. | d | X | 7.80 | 10.00 | X | 9.77 | d | X | 4.00 | 6.30 | X | 6.10 |
| Japan | | | | | | | | | | | | |
| Ishikari | | X | X | X | X | X | | 35.00 | 3.00 | 18.00 | 3.00 | 3.67 |
| Yodo | d | X | X | X | X | X | d | X | 0.00 | 8.00 | X | 6.67 |
| Australia | | | | | | | | | | | | |
| Brisbane Estuary | | X | X | X | 20.00 | X | | X | 9.70 | 5.60 | 5.00 | 5.20 |
| New Zealand | | | | | | | | | | | | |
| Waikato | | X | 10.00 | X | X | X | | X | 1.00 | X | X | X |
| Belgium | | | | | | | | | | | | |
| Meuse-Heer | | X | 1.20 | 1.20 | X | 2.80 | | X | 4.70 | 7.00 | X | 7.50 |
| Meuse-Lanaye | | X | 4.60 | 2.70 | X | 3.40 | | X | 4.50 | 11.30 | X | 12.23 |
| Escaut-Bleharies | | X | 12.60 | 9.80 | X | 12.73 | | X | 6.80 | 15.60 | X | 16.67 |
| Escaut-Doel | | X | 15.60 | 25.10 | X | 24.37 | | X | 15.50 | 24.40 | X | 27.60 |
| Denmark | | | | | | | | | | | | |
| Gudenaa | | X | X | X | X | X | | X | X | X | X | X |
| Skjernaa | | X | X | X | X | X | | X | X | X | X | X |
| Susaa | | X | X | X | X | X | | X | X | X | X | X |
| Finland | | | | | | | | | | | | |
| Tornionjoki | c | X | 1.00 | 3.00 | 0.52 | 2.17 | | X | 2.00 | 2.80 | 1.70 | 1.83 |
| Kymijoki | | X | X | X | 0.67 | 2.22 | | X | X | 1.40 | 1.50 | 1.63 |
| France | | | | | | | | | | | | |
| Loire-Nantes | e | X | 10.00 | 5.00 | 5.00 | 5.00 | e | X | 1.00 | 8.00 | 8.00 | 7.33 |
| Seine-Tancerville | | X | 12.00 | 13.00 | 34.00 | 20.67 | | X | 52.00 | 11.00 | 17.00 | 14.33 |
| Garonne-Bordeaux | | X | 10.00 | 3.00 | X | X | | X | 1.00 | 6.00 | 3.00 | 4.33 |
| Rhine-Selz | | X | 9.00 | 16.00 | 7.60 | 11.50 | | X | 11.30 | 15.90 | 5.10 | 7.80 |
| Germany, Fed Rep | | | | | | | | | | | | |
| Rhine-Bimmen | | X | 40.00 | 19.00 | 9.00 | 11.33 | | X | 24.00 | 16.00 | 19.00 | 18.33 |
| Italy | | | | | | | | | | | | |
| Po | d | X | X | 0.60 | X | X | d | X | 0.60 | 0.85 | X | 0.91 |
| Netherlands | | | | | | | | | | | | |
| Meuse-Keizersveer | | X | 7.00 | 7.00 | 5.00 | 5.00 | | X | 9.00 | 12.00 | 7.00 | 6.33 |
| Meuse-Eijsden | | X | 14.00 | 10.00 | 9.00 | 11.67 | | X | 16.00 | 11.00 | 8.00 | 9.00 |
| Scheur-Maasluis | | X | 16.00 | 19.00 | 6.00 | 7.00 | | X | 15.00 | 12.00 | 6.00 | 7.33 |
| Ijssel-Kampen | | X | 25.00 | 14.00 | 7.00 | 8.67 | | 26.00 | 16.00 | 9.00 | 7.00 | 7.67 |
| Norway | | | | | | | | | | | | |
| Skienselva | | X | X | X | X | X | | X | 4.00 | X | X | X |
| Portugal | | | | | | | | | | | | |
| Tejo | c | X | X | 10.00 | X | X | | X | X | X | X | X |
| Spain | | | | | | | | | | | | |
| Guadalaviar | | X | X | 10.00 | X | 21.20 | | X | X | 2.70 | X | 7.83 |
| Sweden | | | | | | | | | | | | |
| Dalalven | | X | X | X | X | X | | X | X | 17.00 | 17.00 | 16.00 |
| Switzerland | | | | | | | | | | | | |
| Rhine-Village | | X | 1.30 | 2.00 | 0.70 | 1.70 | | X | 1.80 | 4.20 | 3.60 | 4.63 |
| Aare-Brugg | | X | X | X | X | X | | X | X | X | X | X |
| Limmat-Baden | | X | X | X | X | X | | X | X | X | X | X |
| Rhone-Port du Sceaux | | X | X | X | X | X | | X | X | 3.48 | 3.82 | 4.62 |
| United Kingdom | | | | | | | | | | | | |
| Thames | | X | X | X | X | X | | X | X | X | X | X |
| Severn | | X | X | X | X | X | | X | X | X | X | X |
| Clyde | | X | X | X | X | X | | X | X | X | X | X |
| Mersey | | | X | X | X | X | | X | X | X | X | X |
| Yugoslavia | | | | | | | | | | | | |
| Dunav | | X | X | X | X | X | | X | 1.39 | 117.90 | X | 53.27 |
| Drava | | X | X | X | X | X | | X | X | X | X | X |

**Source:** Organization for Economic Cooperation and Development.
0 = zero or less than one-half the unit of measure; X = not available.
a = total concentrations; b = orthophosphate concentrations; c = data represent upper limit (actual averages are lower);
d = dissolved concentrations; e = 1975 data represent upper limit; f = data for 1975 and 1980 represent upper limit.
For additional information, see Sources and Technical Notes.

# Table 9.3 MAJOR RIVER BASINS

| | Countries | Basin Area (1000 square kilometers) | Length (kilometers) | Average Annual Discharge (cubic kilometers per year) | Average Annual Suspended Sediment (million metric tons per year) |
|---|---|---|---|---|---|
| Amazon | Bolivia, Brazil, Ecuador, Colombia, Peru, Venezuela | 7050 | 6280 | 3768 | 363 |
| Zaire (Congo) | Angola, Congo, Zaire, Cameroon, Central African Republic | 3691 | 4200 | 1256 | 65 |
| Mississippi-Missouri | United States, Canada | 3221 | 6019 | 556 | 365 |
| Paraná | Argentina, Paraguay, Brazil, Bolivia | 3103 | 4500 | 493 | 82 |
| Nile | Uganda, Kenya, Zaire, Ethiopia, Tanzania, Sudan, Egypt, Rwanda, Burundi | 2849 | 6671 | 81 | 111 |
| Chang Jiang (Yangtze Kiang) | China | 1807 | 6300 | 688 | 501 |
| Niger | Cameroon, Guinea, Benin, Chad, Ivory Coast, Nigeria, Niger, Mali, Burkina Faso | 1502 | 4160 | 224 | 5 |
| Indus | Pakistan, India, Afghanistan, China | 963 | 3180 | 443 | 436 |
| Brahmaputra | Bangladesh, India, China, Bhutan | 935 | 2900 | 476 | 726 |
| Orinoco | Venezuela, Colombia, Brazil | 906 | 2736 | 538 | 87 |
| Mekong | China, Thailand, Lao PDR, Dem Kampuchea, Viet Nam, Burma | 811 | 4500 | 538 | 170 |
| Huang (Yellow) | China | 684 | 5464 | 104 | 1600 |
| Ganges | India, Bangladesh, Nepal, China, Bhutan | 489 | 2700 | 440 | 1455 |
| Irrawaddy | Burma, China, India | 431 | 2293 | 443 | 299 |

**Sources:** U.S. Geological Survey; Rand McNally; American Society of Agronomy; Soil Science Society of America; The World Bank.
For additional information, see Sources and Technical Notes.

# Table 9.4 FLOODS AND CYCLONES IN SELECTED COUNTRIES, 1960–81

| | Floods: Number of Events | Floods: Deaths |
|---|---|---|
| Brazil | 28 | 2850 |
| India | 28 | 14700 |
| Indonesia | 23 | 1200 |
| Bangladesh | 17 | 39900 |
| Bolivia | 13 | 160 |
| Philippines | 13 | 1400 |
| Algeria | 12 | 190 |
| Mexico | 11 | 370 |
| Colombia | 10 | 600 |
| Argentina | 9 | 200 |
| Korea, Rep | 9 | 1950 |
| Peru | 9 | 350 |
| Viet Nam | 9 | 350 |
| Costa Rica | 8 | 30 |
| Morocco | 8 | 90 |
| Burma | 7 | 140 |
| Ecuador | 7 | 20 |
| Lao People's | 7 | 400 |
| China | 6 | 1650 |
| Iran | 6 | 350 |
| Mozambique | 6 | 850 |
| Nepal | 6 | 1500 |
| Pakistan | 6 | 2100 |
| Panama | 6 | 100 |
| Sri Lanka | 6 | 100 |
| Tunisia | 6 | 700 |
| South Africa | 5 | 280 |
| Tanzania | 5 | 65 |

| | Cyclones: Number of Events | Cyclones: Deaths |
|---|---|---|
| Philippines | 39 | 5650 |
| Bangladesh | 37 | 386200 |
| India | 26 | 24930 |
| Mexico | 14 | 1560 |
| Korea, Rep | 10 | 700 |
| Madagascar | 9 | 970 |
| China | 7 | 170 |
| Hong Kong | 7 | 510 |
| Mauritius | 7 | 15 |
| Burma | 7 | 1350 |
| Haiti | 6 | 5800 |
| Viet Nam | 6 | 7480 |
| French Caribbean | 5 | 100 |

**Source:** League of Red Cross and Red Crescent Societies; U.S. Office of Foreign Disaster Assistance.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 9.1 Freshwater Availability and Use, 1970s

**Source:** J. Forkasiewicz and J. Margat, *Tableau Mondial de Données Nationales D'économie de l'Eau, Ressources et Utilisation* (Departement Hydrogéologie, Orléans, France, 1980).

The amount of water available to a country depends on the amount of precipitation (less evapotranspiration), and its distribution as runoff or groundwater storage. In this table, availability refers to stable streamflow or stable runoff—the base flow of rivers supplied by groundwater—and excludes flood waters and deep ground aquifers. It usually includes both internal and transit sources.

These data are annual averages and do not indicate peak flows or drought periods. Data for small countries and arid and semiarid zones are considered less reliable than the data for larger and wetter countries. Population estimates for the same year as the "Year of Information" were used to calculate per capita availability and withdrawals. If no "Year of Information" data were available, the 1975 population was used to calculate per capita statistics. For 1985 per capita availability data, see Part II, Chapter 8, "Freshwater," Table 8.3.

Water is *withdrawn* when it is taken from a surface or underground source and conveyed to the place of use. Water is *consumed* when it is no longer available for use because it has been removed from available supplies by evaporation or transpiration, by use in agriculture or manufacturing, or for human consumption. The amount of water withdrawn per person was calculated by dividing the estimated total withdrawal by the total population for that year.

Water use is generally classified in four categories: public supplies (principally for use in homes and commercial establishments), agriculture (principally for use in irrigation), industry (self-supplied use), and thermoelectric cooling (principally for use in cooling fossil fuel and nuclear power plants).

Because not all countries use these categories, the sectoral data are not strictly comparable. Data were included in the table if statistics for two or more sectors were available from the source document.

Omitted are instream uses of water such as hydroelectric power generation, navigation, habitat for fish and other aquatic life, and recreation.

For additional information on water resources, see M.I. L'vovich, *World Water Resources and Their Future* (Mysl' P.H. Moscow, 1974); English translation edited by Raymond L. Nace (American Geophysical Union, 1979).

### Table 9.2 Water Quality, Selected Rivers, 1970–83

**Source:** Organization for Economic Co-operation and Development (OECD), *OECD Environmental Data Compendium 1985* (OECD, Paris, 1985), pp. 54–59.

The data in this table were collected from OECD member countries using questionnaires. Countries were asked to submit data that could be used to assess trends in water quality in major rivers over the years 1970 to 1983. For each river an attempt was made to monitor the ambient concentration of a pollutant (or the effects of pollutants) at a site at the mouth or the downstream frontier of the river. The OECD notes in the *Compendium* that these data should be used to compare trends within countries rather than between countries because monitoring methods vary from country to country. Data acceptable to OECD were compiled for 39 rivers (or river segments) in 18 member countries.

In a few cases data shown for 1970, 1975, and 1980 may represent data for adjacent years.

All data for the Waikato River in New Zealand are approximate.

Data for the Brisbane Estuary in Australia may not be comparable because measurements were made by different authorities. Data for 1972–75 are not comparable with those of later years because of different monitoring methods.

### Table 9.3 Major River Basins

**Sources:** River length and country listing: Rand McNally, *The Great Geographic Atlas* (Rand McNally, Chicago, New York, San Francisco, 1982). Basin area and annual discharge: U.S. Geological Survey (USGS), *Water Quality and Availability* (USGS, Washington, unpublished manuscript, December 1983). Suspended load for Chang Jiang, Indus, and Paraná rivers: Alfredo Sfeir-Younis, *Soil Conservation in Developing Countries* (The World Bank, Washington, unpublished manuscript, 1985). Suspended load for all other rivers: S.A. El-Swaify and E.W. Dangler, "Rainfall Erosion in the Tropics: A State-of-the-Art," in *Soil Erosion and Conservation in the Tropics* (American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, 1982).

Rivers were chosen on the basis of basin area size. Omitted were those with relatively little human impact (Amur, USSR; Ob, USSR; Yenisey, USSR; Yukon, United States; Nelson, Canada), or for which comparable data were not available.

River length refers to the longest branch of the river, not necessarily the length of the main stream.

Both El-Swaify and Sfeir-Younis base their sediment analyses on data from J.N. Holeman, "The Sediment Yield of Major Rivers of the World," *Water Resources Research* (Soil Conservation Service, Washington, D.C., 1968). Both analysts have modified Holeman's data extensively. Many of the original data were derived from brief periods of sediment sampling during the 1930s, 1940s, and 1950s.

### Table 9.4 Floods and Cyclones in Selected Countries, 1960–81

**Source:** Gunnar Hagman, *et al., Prevention Better Than Cure, Report on Human and Environmental Disasters in the Third World* (The Swedish Red Cross, Stockholm, 1984).

Data on flood and cyclone disasters are compiled by the League of Red Cross and Red Crescent Societies and the U.S. Department of State, Office of Foreign Disaster Assistance (OFDA).

The League maintains a List of Major Appeals and Relief Actions that include events that were subject to major Red Cross or Red Crescent actions from 1919 to the present. The records include information about the date and location of the disaster, and the amount of aid donated for relief. The League recorded 389 disasters from 1960 to 1981.

The OFDA maintains a Disaster History List that provides information on: the date, location, and type of event; the number of persons killed, affected, injured, and homeless; and, for some events, damage estimates in U.S. dollars. Using records dating back to 1900, the OFDA has recorded over 1,622 disasters through 1981. Because there are wide discrepencies in the data prior to 1960, only 1960–81 data are used. Data for the developed countries are not included.

The League and OFDA have comparable records of 227 disaster events from 1960 to 1981. Both sources also have listings of many additional events that are not comparable; these are excluded from this table.

Only those countries that suffered five or more disasters during 1961–81 are listed in the table. The data are believed to underrepresent Africa.

# 10. Oceans and Coasts

The tables in this section provide information on national claims to coastal resources, fish catch, tropical coastal resources, and marine pollution.

Table 10.1 presents information on the length of coastlines, jurisdictional claims to coastal waters, and annual marine fish catch by country. Three types of jurisdictional claims are covered: territorial seas, Exclusive Economic Zones (EEZs), and continental shelves. Territorial seas are areas claimed by a country as sovereign territory. EEZ and continental shelf claims are economic in nature—claims to living and non-living resources. The past 11 years—since the Third U.N. Conference on the Law of the Sea began in 1974—have seen a remarkable transition in control over coastal resources as more than 50 countries have established EEZs. A significant part of the coastal seas, once a global commons, has come under the authority of nation states in this short time.

Marine fish harvests, also shown in Table 10.1, include national totals averaged over a two-year period. These totals include fish caught by a country's fleet anywhere in the world. Japan, for example, took 45 percent of its 1982 catch from the nearby Northwest Pacific fishery and the remainder from 16 of the other 17 marine fishery areas around the world.

Harvests from most of the world's marine fisheries, shown in Table 10.2, have changed in the last decade. The catch from the three Antarctic fisheries has increased markedly, although it remains small in absolute terms. The harvest from the Northwest Pacific fishery, source of 30 percent of the world's marine catch, grew by 24 percent, with most of the growth coming from increased harvests of herring, sardines, anchovies, and related species. The second largest fishery, the Northeast Atlantic, experienced little change.

The U.N. Food and Agriculture Organization (FAO) compiles fishery statistics in cooperation with regional fishery commissions and national governments. Several problems, however, hamper the collection and analysis of these data. First, the diversity of species within a fishery makes classification of the catch by species group difficult, especially for tropical fisheries. As a result, a large fraction of the catch is labeled "miscellaneous," which prevents marine scientists from assessing the sustainable yield of a particular species or fishery. Second, it is believed that the overall quality of the data has declined over the past 10–15 years. In the 1960s, regional fishery commissions played an active role in collecting and checking data, while the FAO performed the same functions at the global level. As more fishery areas came under national jurisdiction, the influence of regional fishery commissions declined, but without a commensurate strengthening of national fishery offices. At the same time, FAO's fishery statistics staff was cut.

Management agreements also affect data collection. Catch quotas can be an incentive for underreporting at the local level and at the national level when several nations share a managed fishery.

The latest information available on the extent and length of three important coastal resources—mangrove forests, coral reefs, and seagrass beds—is presented in Table 10.3. Found principally in the tropics, these salt-tolerant ecosystems provide valuable goods and services: they stabilize coastlines, dissipate wave energy, buffer salinity changes in coastal waters, retain sediments and nutrients, and support fisheries and tourism.

Data for Table 10.3 are preliminary estimates gathered from recent assessments, maps, and a questionnaire sent to country and regional experts. Because there has been no systematic monitoring of tropical coastal resources, the data base required to fully analyze trends in the extent, use, and condition of these resources does not exist.

A number of kinds of pollution can seriously damage renewable coastal resources and threaten the health of residents, visitors, and all who eat marine organisms. These pollutants include sediments, heavy metals, organochlorine compounds, petroleum hydrocarbons, sewage, and radioactive and other industrial, agricultural, and domestic effluents.

Each type of pollution tends to have a distinct effect on different ecosystems. Oil spills, for example, can seriously degrade beaches and harm waterfowl; sedimentation and organic wastes are particularly harmful to coral reefs.

Time series data on one of these pollutants, petroleum from tanker spills, are provided in Table 10.4.

The amount of oil spilled into the oceans during the early 1980s is substantially less than that spilled in the late 1970s. However, one large accident can distort the year-to-year trends. For example, in 1983, the *Castello de Belver*, a Spanish tanker, spilled 255,525 metric tons of petroleum off the coast of South Africa—two thirds of all the oil spilled that year.

# Table 10.1 COASTAL AREAS AND RESOURCES, 1972–83

| | Length of Marine Coastline (kilometers) | Maritime Zones (nautical miles unless indicated otherwise) Territorial Sea | Exclusive Economic Zone | Continental Shelf | Average Annual Marine Fish Catch 1982–83 (thousand metric tons) | Percent Change Over 1972–73 |
|---|---|---|---|---|---|---|
| **WORLD** | | | | | | |
| **AFRICA** | | | | | | |
| Algeria | 1183 | 12 | X | X | 67 | 126 |
| Angola | 1600 | 20 | X | 200 | 104 | -81 |
| Benin | 121 | 200 | X | X | 4 | -60 |
| Botswana | 0 | NA | NA | NA | 0 | NA |
| Burkina Faso | 0 | NA | NA | NA | 0 | NA |
| Burundi | 0 | NA | NA | NA | 0 | NA |
| Cameroon | 402 | 50 | X | X | 42 | 141 |
| Cape Verde | 965 | 12 | 200 | X | 12 | 92 |
| Central African Rep | 0 | NA | NA | NA | 0 | NA |
| Chad | 0 | NA | NA | NA | 0 | NA |
| Comoros | 340 | 12 | 200 | X | 4 | 33 |
| Congo | 169 | 200 | X | X | 19 | 22 |
| Djibouti | 314 | 12 | 200 | X | 0 | 184 |
| Egypt | 2450 | 12 | X | 200m/EXP | 25 | -25 |
| Equatorial Guinea | 296 | 12 | 200 | X | 3 | -38 |
| Ethiopia | 1094 | 12 | X | X | 0 | -99 |
| Gabon | 885 | 100 | X | X | 50 | 1011 |
| Gambia | 80 | 12 | X | X | 8 | 6 |
| Ghana | 539 | 200 | X | 100f | 192 | -11 |
| Guinea | 346 | 12 | 200 | X | 17 | 121 |
| Guinea-Bissau | 274 | 12 | 200 | X | 3 | 93 |
| Ivory Coast | 515 | 12 | 200 | 200 | 78 | 16 |
| Kenya | 536 | 12 | 200 | 200m/EXP | 7 | 15 |
| Lesotho | 0 | NA | NA | NA | 0 | NA |
| Liberia | 579 | 200 | X | X | 10 | 87 |
| Libya | 1770 | 12 | X | X | 7 | 182 |
| Madagascar | 4828 | 12 | 200 | 150 | 11 | -25 |
| Malawi | 0 | NA | NA | NA | 0 | NA |
| Mali | 0 | NA | NA | NA | 0 | NA |
| Mauritania | 754 | 70 | 200 | 200/CM | 45 | 47 |
| Mauritius | 177 | 12 | 200 | 200/CM | 10 | 47 |
| Morocco | 1835 | 12 | 200 | X | 400 | 25 |
| Mozambique | 2470 | 12 | 200 | X | 36 | 204 |
| Niger | 0 | NA | NA | NA | 0 | NA |
| Nigeria | 853 | 30 | 200 | 200m/EXP | 357 | 56 |
| Rwanda | 0 | NA | NA | NA | 0 | NA |
| Senegal | 531 | 12 | 200 | 200/CM | 213 | -19 |
| Sierra Leone | 402 | 200 | X | 200m/EXP | 37 | -37 |
| Somalia | 3025 | 200 | X | X | 15 | 99 |
| South Africa | 2881 | 12 | X | 200m/EXP | 611 | -5 |
| Sudan | 853 | 12 | X | 200m/EXP | 3 | 525 |
| Swaziland | 0 | NA | NA | NA | 0 | NA |
| Tanzania, United Rep | 1424 | 50 | X | X | 30 | 12 |
| Togo | 56 | 30 | 200 | X | 12 | 61 |
| Tunisia | 1143 | 12 | X | X | 65 | 119 |
| Uganda | 0 | NA | NA | NA | 0 | NA |
| Zaire | 37 | 12 | X | X | 1 | -93 |
| Zambia | 0 | NA | NA | NA | 0 | NA |
| Zimbabwe | 0 | NA | NA | NA | 0 | NA |
| **NORTH AMERICA** | | | | | | |
| Barbados | 97 | 12 | 200 | X | 5 | 104 |
| Canada | 90908 | 12 | X | 200m/EXP | 1316 | 22 |
| Costa Rica | 1290 | 12 | 200 | 200m/EXP | 10 | -3 |
| Cuba | 3735 | 12 | 200 | X | 183 | 27 |
| Dominican Rep | 1288 | 6 | 200 | 200/CM | 11 | 70 |
| El Salvador | 307 | 200 | X | X | 10 | -6 |
| Guatemala | 400 | 12 | 200 | 200m/EXP | 4 | 21 |
| Haiti | 1771 | 12 | 200 | 200m/EXP | 4 | 19 |
| Honduras | 820 | 12 | 200 | 200m/EXP | 7 | 51 |
| Jamaica | 1022 | 12 | X | 200m/EXP | 8 | -15 |
| Mexico | 9330 | 12 | 200 | 200m/EXP | 1180 | 178 |
| Nicaragua | 910 | 200 | X | X | 4 | -59 |
| Panama | 2490 | 200 | X | X | 139 | 79 |
| Trinidad and Tobago | 362 | 12 | X | 200m/EXP | 4 | 16 |
| United States | 19924 | 3 | 200 | 200m/EXP | 3991 | 48 |
| **SOUTH AMERICA** | | | | | | |
| Argentina | 4989 | 200 | X | 200m/EXP | 431 | 79 |
| Bolivia | 0 | NA | NA | NA | 0 | NA |
| Brazil | 7491 | 200 | X | X | 634 | 11 |
| Chile | 6435 | 3 | X | 350 | 3825 | 423 |
| Colombia | 2414 | 12 | 200 | 200m/EXP | 17 | -42 |
| Ecuador | 2237 | 200 | X | 200m | 481 | 267 |
| Guyana | 459 | 12 | X | 200/CM | 26 | 42 |
| Paraguay | 0 | NA | NA | NA | 0 | NA |
| Peru | 2414 | X | X | 200 | 2465 | -30 |
| Suriname | 386 | 12 | 200 | X | 3 | -18 |
| Uruguay | 660 | 200 | X | 200m/EXP | 131 | 590 |
| Venezuela | 2800 | 12 | 200 | 200m/EXP | 202 | 35 |

# Table 10.1

| | Length of Marine Coastline (kilometers) | Maritime Zones (nautical miles unless indicated otherwise) | | | Average Annual Marine Fish Catch | |
|---|---|---|---|---|---|---|
| | | Territorial Sea | Exclusive Economic Zone | Continental Shelf | 1982–83 (thousand metric tons) | Percent Change Over 1972–73 |
| **ASIA** | | | | | | |
| Afghanistan | 0 | NA | NA | NA | 0 | NA |
| Bahrain | 161 | X | X | X | 7 | 344 |
| Bangladesh | 580 | 12 | 200 | X | 143 | 63 |
| Bhutan | 0 | NA | NA | NA | 0 | NA |
| Burma | 3060 | 12 | 200 | 200/CM | 447 | 34 |
| China | 14500 | 12 | X | X | 3369 | 22 |
| Cyprus | 648 | 12 | X | 200m/EXP | 2 | 23 |
| India | 7000 | 12 | 200 | 200/CM | 1501 | 38 |
| Indonesia | 54716 | 12 | 200 | X | 1538 | 79 |
| Iran | 3180 | 12 | X | X | 33 | 95 |
| Iraq | 58 | 12 | X | X | 9 | 149 |
| Israel | 273 | 6 | X | 200m/EXP | 10 | −24 |
| Japan | 13685 | 12 | X | X | 10789 | 11 |
| Jordan | 26 | 3 | X | X | 0 | −82 |
| Kampuchea, Dem | 443 | 12 | 200 | 200m/EXP | 5 | −67 |
| Korea, Dem People's Rep | 2495 | X | 200 | X | 1488 | 79 |
| Korea, Rep | 2413 | 12 | X | X | 2295 | 72 |
| Kuwait | 499 | 12 | X | X | 4 | −6 |
| Lao People's Dem Rep | 0 | NA | NA | NA | 0 | NA |
| Lebanon | 225 | 6 | X | X | 1 | −36 |
| *Malaysia* | *2068* | 12 | X | *200m/EXP* | 696 | *75* |
| Mongolia | 0 | NA | NA | NA | 0 | NA |
| Nepal | 0 | NA | NA | NA | 0 | NA |
| Oman | 2092 | 12 | 200 | X | 99 | −45 |
| Pakistan | 1046 | 12 | 200 | 200/CM | 281 | 42 |
| Philippines | 22540 | X | 200 | EXP | 1265 | 19 |
| Qatar | 563 | 3 | X | X | 2 | 6 |
| Saudi Arabia | 2510 | 12 | X | X | 26 | 5 |
| Singapore | 193 | 3 | X | X | 19 | 16 |
| *Sri Lanka* | 1340 | 12 | *200* | *200/CM* | 186 | 99 |
| Syrian Arab Rep | 193 | 35 | X | X | 1 | 3 |
| Thailand | 3219 | 12 | X | 200m/EXP | 2043 | 32 |
| Turkey | 7200 | 6 | X | X | 498 | 209 |
| United Arab Emirates | 1448 | 3 | X | X | 72 | 67 |
| Viet Nam | 3444 | 12 | 200 | 200/CM | 473 | −43 |
| Yemen | 523 | 12 | X | X | 13 | 36 |
| Yemen, Dem | 1383 | 12 | 200 | 200/CM | 72 | 156 |
| **EUROPE** | | | | | | |
| Albania | 418 | 15 | X | 200m/EXP | 4 | 0 |
| Austria | 0 | NA | NA | NA | 0 | NA |
| Belgium | 64 | 3 | X | X | 48 | −14 |
| Bulgaria | 354 | 12 | X | 200m/EXP | 104 | 4 |
| Czechoslovakia | 0 | NA | NA | NA | 0 | NA |
| Denmark | 3379 | 3 | X | 200m/EXP | 1871 | 30 |
| Finland | 1126 | 4 | X | 200m/EXP | 118 | 56 |
| *France* | *3427* | 12 | *200* | *200m/EXP* | 765 | −3 |
| German Dem Rep | 901 | 3 | X | 200m/EXP | 218 | −35 |
| Germany, Fed Rep | 1488 | 3 | X | 200m/EXP | 287 | −34 |
| Greece | 13676 | 6 | X | 200m/EXP | 89 | 1 |
| Hungary | 0 | NA | NA | NA | 0 | NA |
| Ireland | 1448 | 3 | X | X | 208 | 128 |
| Italy | 4996 | 12 | X | 200m/EXP | 437 | 10 |
| Luxembourg | 0 | NA | NA | NA | 0 | NA |
| Malta | 140 | 12 | X | 200m/EXP | 1 | −22 |
| Netherlands | 451 | 12 | X | 200m/EXP | 500 | 46 |
| Norway | 3419 | 4 | 200 | 200m/EXP | 2642 | −12 |
| Poland | 491 | 12 | X | 200m/EXP | 643 | 19 |
| Portugal | 860 | 12 | 200 | 200m/EXP | 250 | −46 |
| Romania | 225 | 12 | X | 200m/EXP | 184 | 229 |
| Spain | 4964 | 12 | 200 | 200m/EXP | 1286 | −16 |
| Sweden | 3218 | 12 | X | 200m/EXP | 253 | 17 |
| Switzerland | 0 | NA | NA | NA | 0 | NA |
| United Kingdom | 12429 | 3 | X | 200m/EXP | 871 | −21 |
| Yugoslavia | *1521* | 12 | X | 200m/EXP | 47 | 53 |
| **USSR** | **46670** | **12** | **200** | **200m/EXP** | **9057** | **24** |
| **OCEANIA** | | | | | | |
| Australia | 25760 | 3 | X | 200m/EXP | 168 | 40 |
| Fiji | 1129 | 12 | 200 | 200m/EXP | 26 | 456 |
| New Zealand | 15134 | 12 | 200 | 200/CM | 130 | 110 |
| Papua New Guinea | 5152 | 12 | X | 200m/EXP | 1 | −96 |
| Solomon Islands | 5313 | 12 | *200* | X | 40 | 400 |
| **ANTARCTICA** | | | | | | |

**Sources:** U.S. Department of State; U.N. Law of the Sea Secretariat; U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; X = no claim made or information not available; NA = not applicable; m = meters of water (depth); f = fathom (1.83 meters); CM = edge of continental margin; EXP = limits of exploitable resources.
For additional information, see Sources and Technical Notes.

# Table 10.2 MARINE FISHERY PRODUCTION BY SPECIES GROUP, 1972-83

| | Average Annual Catch (thousand metric tons) | | Share of Catch (percent) | | Change in Catch 1982-83 over 1972-73 (percent) |
|---|---|---|---|---|---|
| | 1972-73 | 1982-83 | 1972-73 | 1982-83 | |
| **ALL MARINE FISHERIES** | | | | | |
| **Total catch** | **57853** | **67822** | | | **17** |
| **Atlantic Northwest** | | | | | |
| Total catch | 4395 | 2755 | 100 | 100 | -37 |
| Cods, hakes, haddocks | 1461 | 921 | 33 | 33 | -37 |
| Herrings, sardines, anchovies | 852 | 497 | 19 | 18 | -42 |
| All others | 2082 | 1337 | 47 | 49 | -36 |
| **Atlantic Northeast** | | | | | |
| Total catch | 10990 | 10946 | 100 | 100 | 0 |
| Cods, hakes, haddocks | 4001 | 3786 | 36 | 35 | -5 |
| Jacks, mullets, sauries | 2154 | 2340 | 20 | 21 | 9 |
| All others | 4836 | 4820 | 44 | 44 | 0 |
| **Atlantic, Western Central** | | | | | |
| Total catch | 1439 | 2212 | 100 | 100 | 54 |
| Herrings, sardines, anchovies | 625 | 1039 | 43 | 47 | 66 |
| Redfishes, basses, congers | 200 | 154 | 14 | 7 | -23 |
| Oysters | 151 | 228 | 10 | 10 | 51 |
| All others | 463 | 791 | 32 | 36 | 71 |
| **Atlantic, Eastern Central** | | | | | |
| Total catch | 3283 | 3189 | 100 | 100 | -3 |
| Herrings, sardines, anchovies | 1058 | 856 | 32 | 27 | -19 |
| Jacks, mullets, sauries | 651 | 577 | 20 | 18 | -11 |
| All others | 1575 | 1757 | 48 | 55 | 12 |
| **Mediterranean and Black Sea** | | | | | |
| Total catch | 1160 | 1885 | 100 | 100 | 62 |
| Herrings, sardines, anchovies | 502 | 957 | 43 | 51 | 91 |
| Miscellaneous marine fishes | 127 | 144 | 11 | 8 | 13 |
| Jacks, mullets, sauries | 97 | 165 | 8 | 9 | 70 |
| All others | 434 | 619 | 37 | 33 | 43 |
| **Atlantic, Southwest** | | | | | |
| Total catch | 875 | 1587 | 100 | 100 | 81 |
| Herrings, sardines, anchovies | 218 | 245 | 25 | 15 | 13 |
| Redfishes, basses, congers | 192 | 263 | 22 | 17 | 37 |
| Cods, hakes, haddocks | 162 | 567 | 18 | 36 | 251 |
| All others | 304 | 512 | 35 | 32 | 69 |
| **Atlantic, Southeast** | | | | | |
| Total catch | 3087 | 2354 | 100 | 100 | -24 |
| Cods, hakes, haddocks | 1014 | 462 | 33 | 20 | -54 |
| Herrings, sardines, anchovies | 1178 | 728 | 38 | 31 | -38 |
| Jacks, mullets, sauries | 449 | 783 | 15 | 33 | 74 |
| All others | 446 | 380 | 14 | 16 | -15 |
| **Atlantic, Antarctic** | | | | | |
| Total catch | 1 | 384 | 100 | 100 | 26409 |
| Redfishes, basses, congers | 1 | 114 | 100 | 30 | 7783 |
| Krill, planktonic crustaceans | 0 | 254 | 0 | 66 | NM |
| All others | 0 | 16 | 0 | 4 | NM |
| **Indian Ocean, Western** | | | | | |
| Total catch | 1827 | 2108 | 100 | 100 | 15 |
| Miscellaneous marine fishes | 457 | 231 | 25 | 11 | -49 |
| Herrings, sardines, anchovies | 314 | 440 | 17 | 21 | 40 |
| Redfishes, basses, congers | 271 | 447 | 15 | 21 | 65 |
| All others | 786 | 990 | 43 | 47 | 26 |

| | Average Annual Catch (thousand metric tons) | | Share of Catch (percent) | | Change in Catch 1982-83 over 1972-73 (percent) |
|---|---|---|---|---|---|
| | 1972-73 | 1982-83 | 1972-73 | 1982-83 | |
| **Indian Ocean, Eastern** | | | | | |
| Total catch | 848 | 1716 | 100 | 100 | 102 |
| Miscellaneous marine fishes | 462 | 794 | 54 | 46 | 72 |
| Redfishes, basses, congers | 86 | 159 | 10 | 9 | 84 |
| Herrings, sardines, anchovies | 69 | 167 | 8 | 10 | 142 |
| All others | 231 | 596 | 27 | 35 | 159 |
| **Indian Ocean, Antarctic** | | | | | |
| Total catch | 63 | 145 | 100 | 100 | 130 |
| Redfishes, basses, congers | 58 | 30 | 93 | 21 | -48 |
| Miscellaneous marine fishes | 5 | 0 | 7 | 0 | -96 |
| Krill, planktonic crustaceans | 0 | 114 | 0 | 79 | NM |
| All others | 0 | 0 | 0 | 0 | NM |
| **Pacific, Northwest** | | | | | |
| Total catch | 16785 | 20770 | 100 | 100 | 24 |
| Miscellaneous marine fishes | 5273 | 4124 | 31 | 20 | -22 |
| Cods, hakes, haddocks | 3471 | 3824 | 21 | 18 | 10 |
| Herrings, sardines, anchovies | 1133 | 4737 | 7 | 23 | 318 |
| All others | 6907 | 8085 | 41 | 39 | 17 |
| **Pacific, Northeast** | | | | | |
| Total catch | 2338 | 2326 | 100 | 100 | -1 |
| Cods, hakes, haddocks | 1258 | 1341 | 54 | 58 | 7 |
| Redfishes, basses, congers | 269 | 142 | 12 | 6 | -47 |
| Salmons, trouts, smelts | 184 | 351 | 8 | 15 | 90 |
| All others | 627 | 492 | 27 | 21 | -22 |
| **Pacific, Western Central** | | | | | |
| Total catch | 4892 | 5996 | 100 | 100 | 23 |
| Miscellaneous marine fishes | 2041 | 1608 | 42 | 27 | -21 |
| Jacks, mullets, sauries | 551 | 700 | 11 | 12 | 27 |
| Tunas, bonitos, billfishes | 449 | 910 | 9 | 15 | 103 |
| All others | 1850 | 2778 | 38 | 46 | 50 |
| **Pacific, Eastern Central** | | | | | |
| Total catch | 1255 | 1992 | 100 | 100 | 59 |
| Tunas, bonitos, billfishes | 338 | 364 | 27 | 18 | 8 |
| Herrings, sardines, anchovies | 301 | 982 | 24 | 49 | 226 |
| All others | 615 | 646 | 49 | 32 | 5 |
| **Pacific, Southwest** | | | | | |
| Total catch | 283 | 283 | 100 | 100 | 0 |
| Tunas, bonitos, billfishes | 73 | 41 | 26 | 15 | -44 |
| Redfishes, basses, congers | 52 | 119 | 19 | 42 | 126 |
| Squids, cuttlefishes, octopuses | 8 | 74 | 3 | 26 | 845 |
| All others | 150 | 49 | 53 | 17 | -67 |
| **Pacific, Southeast** | | | | | |
| Total catch | 4332 | 7032 | 100 | 100 | 62 |
| Herrings, sardines, anchovies | 3532 | 4597 | 82 | 65 | 30 |
| Jacks, mullets, sauries | 145 | 1951 | 3 | 28 | 1246 |
| All others | 655 | 484 | 15 | 7 | -26 |
| **Pacific, Antarctic** | | | | | |
| Total catch | 0 | 9 | NM | 100 | NM |
| Krill, planktonic crustaceans | 0 | 9 | NM | 99 | NM |
| All others | 0 | 0 | NM | 1 | NM |

**Source:** U.N. Food and Agriculture Organization.
0 = zero or less than one-half the unit of measure; NM = not meaningful.
For additional information, see Sources and Technical Notes.

# Table 10.3 TROPICAL COASTAL RESOURCES, EARLY 1980s

| | Total Coastline (kilometers) | Mangrove Forests: Area (square kilometers) | Mangrove Forests: Length (kilometers) | Mangrove Forests: Length as Percentage of Total Coastline | Seagrass Beds: Area (square kilometers) | Seagrass Beds: Length (kilometers) | Seagrass Beds: Length as Percentage of Total Coastline | Coral Reefs: Area (square kilometers) | Coral Reefs: Length (kilometers) | Coral Reefs: Length as Percentage of Total Coastline |
|---|---|---|---|---|---|---|---|---|---|---|
| **AFRICA** | | | | | | | | | | |
| Angola | 1600 | 500 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Benin | 121 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Cameroon | 402 | 2720 | 125 | 31 | 0 | 0 | 0 | 0 | 0 | 0 |
| Comoros | 340 | P | P | X | P | P | X | P | 340 | 100 |
| Congo | 169 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Djibouti[a] | 314 | P | P | X | P | P | X | P | P | X |
| Egypt (Red Sea, Gulfs of Aqaba and Suez) | 1550 | P | P | X | P | P | X | P | 1100 | 80 |
| Equatorial Guinea | 296 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Ethiopia | 1094 | P | P | X | P | P | X | P | 321 | 29 |
| Gabon | 885 | 2500 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Gambia | 80 | 650 | P | X | X | X | X | 0 | 0 | 0 |
| Ghana | 539 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Guinea | 346 | 2600 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Guinea-Bissau | 274 | 2430 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Ivory Coast | 515 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Kenya | 536 | 587 | P | X | P | P | X | P | 400 | 75 |
| Liberia | 579 | 400 | 50 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Madagascar | 4828 | 3207 | 1150 | 24 | P | P | X | P | P | X |
| Mauritania | 754 | X | X | X | X | X | X | 0 | 0 | 0 |
| Mauritius[b] | 217 | P | P | X | P | P | X | 36273 | 210 | 97 |
| Rodrigues Island[c] | 40 | X | X | X | X | X | X | 200 | 60 | 150 |
| Mozambique | 2470 | 850 | 1194 | 48 | P | P | X | 2500 | P | X |
| Namibia | 1489 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Nigeria | 853 | 9730 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Reunion | 201 | X | X | X | 0 | 0 | 0 | P | P | X |
| Sao Tome | 209 | X | X | X | 0 | 0 | 0 | P | P | X |
| Senegal | 531 | 4400 | 40 | 8 | X | X | X | 0 | 0 | 0 |
| Seychelles[b] | 491 | P | P | X | P | P | X | 20093 | 245 | 50 |
| Sierra Leone | 402 | 1000 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Somalia | 3025 | P | P | X | P | P | X | P | P | X |
| South Africa | 2881 | 11 | P | X | P | P | X | P | P | X |
| Sudan | 853 | P | P | X | P | P | X | P | 963 | 113 |
| Tanzania[d] | 922 | 960 | P | X | P | P | X | 2183 | 750 | 81 |
| Togo | 56 | X | X | X | 0 | 0 | 0 | 0 | 0 | 0 |
| Zaire | 37 | 200 | P | X | 0 | 0 | 0 | 0 | 0 | 0 |
| **AMERICAS** | | | | | | | | | | |
| Bahamas | 3542 | P | P | X | 38486 | 1638 | 46 | P | 1727 | 49 |
| Belize[e] | 386 | 2400 | 386 | 100 | 650 | 386 | 100 | P | 474 | 123 |
| Bermuda | 103 | X | X | X | X | X | X | P | P | X |
| Brazil | 7491 | 25000 | P | X | P | P | X | P | P | X |
| Caymans | X | P | P | X | P | P | X | P | P | X |
| Colombia[f g] | 2414 | 4400 | P | X | 27327 | 1001 | 41 | P | 500 | 21 |
| Costa Rica[f] | 1290 | 390 | 210 | 16 | 2457 | 136 | 11 | 6 | 2.5 | 0.2 |
| Cuba | 3735 | 4000 | P | X | 42752 | 1092 | 29 | P | 1046 | 28 |
| Dominican Republic | 1288 | 90 | P | X | 3726 | 273 | 21 | P | 455 | 35 |
| Ecuador | 2237 | 2158 | P | X | P | P | X | P | P | X |
| El Salvador | 307 | 450 | 100 | 33 | P | P | X | 0 | 0 | 0 |
| French Guiana | 378 | 55 | P | X | P | P | X | 0 | 0 | 0 |
| Guatemala | 400 | 500 | 100 | 25 | 3312 | 182 | 46 | 0 | 0 | 0 |
| Guyana | 459 | 1500 | P | X | P | P | X | 0 | 0 | 0 |
| Haiti | 1771 | 180 | P | X | P | P | X | P | 182 | 10 |
| Honduras[a f] | 820 | 3000 | 435 | 53 | 22362 | 546 | 67 | P | 364 | 44 |
| Jamaica[d] | 1022 | 70 | P | X | 327 | 273 | 27 | P | 442 | 43 |
| Lesser Antilles[h] | 2138 | 378 | 212 | 10 | 505 | 258 | 12 | P | 796 | 37 |
| Mexico | 10000 | 6600 | P | X | P | 1000 | 10 | P | 820 | 8 |
| Netherlands Antilles[i] | 364 | 5 | 22 | 6 | 36 | 53 | 14 | P | 172 | 47 |
| Nicaragua[a f] | 910 | 600 | 700 | 77 | 28129 | 636 | 70 | P | 455 | 50 |
| Panama[f g] | 2490 | 4860 | 880 | 35 | 9000 | 500 | 20 | P | 320 | 13 |
| Peru | 2414 | 280 | P | X | X | X | X | 0 | 0 | 0 |
| Puerto Rico | 498 | 65 | P | X | 828 | 91 | 18 | P | 182 | 36 |
| Suriname | 386 | 1150 | P | X | P | P | X | 0 | 0 | 0 |
| Trinidad and Tobago | 583 | 81 | 63 | 11 | 414 | 46 | 8 | 13 | 22 | 4 |
| Turks and Caicos | 351 | P | P | X | P | P | X | P | P | X |
| US Gulf States | 4800 | 2050 | P | X | 28393 | 2500 | 52 | P | 866 | 18 |
| Venezuela[a] | 2800 | 6736 | 1102 | 39 | 2542 | 288 | 10 | P | 227 | 8 |

*(continued on next page.)*

# Table 10.3 CONTINUED

| | Total Coastline (kilometers) | Mangrove Forests: Area (square kilometers) | Mangrove Forests: Length (kilometers) | Mangrove Forests: Length as Percentage of Total Coastline | Seagrass Beds: Area (square kilometers) | Seagrass Beds: Length (kilometers) | Seagrass Beds: Length as Percentage of Total Coastline | Coral Reefs: Area (square kilometers) | Coral Reefs: Length (kilometers) | Coral Reefs: Length as Percentage of Total Coastline |
|---|---|---|---|---|---|---|---|---|---|---|
| **ASIA** | | | | | | | | | | |
| Andaman and Nicobar Islands | 500 | 100 | 300 | 60 | P | P | X | P | 325 | 65 |
| Bahrain | 161 | P | P | X | P | P | X | P | P | X |
| Bangladesh | 580 | 4050 | P | X | P | P | X | 0 | 0 | 0 |
| Brunei | 161 | 70 | P | X | P | P | X | 0 | 0 | 0 |
| Burma | 3060 | 5171 | P | X | P | P | X | P | P | X |
| Chagos Archipelago | X | X | X | X | P | P | X | P | P | X |
| China[a] | 14500 | 670 | P | X | P | P | X | P | P | X |
| Hong Kong | 733 | X | P | X | P | P | X | 0 | 0 | 0 |
| India (Peninsular) | 6000 | 3565 | 380 | 6.3 | P | P | X | P | 420 | 7 |
| Indonesia | 81000 | 36000 | 9696 | 12 | P | P | X | P | 17500 | 22 |
| Iran[a] | 3180 | X | X | X | P | P | X | P | P | X |
| Iraq | 59 | X | X | X | P | P | X | 0 | 0 | 0 |
| Israel (Gulf of Aqaba) | 10 | X | X | X | X | X | X | P | 9 | 90 |
| Japan: Nansei Shoto | 1500 | X | X | X | P | P | X | P | 1200 | 80 |
| Jordan | 26 | X | X | X | P | P | X | P | 13 | 50 |
| Kampuchea, Dem | 443 | 100 | P | X | P | P | X | P | 130 | 29 |
| Kuwait | 499 | X | X | X | P | P | X | P | P | X |
| Laccidive Islands | 500 | X | X | X | P | P | X | P | P | X |
| Malaysia | 4675 | 5700 | 2971 | 64 | P | P | X | P | 1670 | 36 |
| Maldives | 644 | X | X | X | P | P | X | P | 644 | 100 |
| Oman | 2092 | P | 84 | 4 | P | P | X | P | 625 | 30 |
| Pakistan | 1046 | 2495 | P | X | P | P | X | 0 | 0 | 0 |
| Philippines | 22450 | 1461 | 4009 | 18 | P | P | X | P | 22450 | 100 |
| Qatar | 563 | X | X | X | P | P | X | P | P | X |
| Saudi Arabia | 2510 | X | X | X | X | X | X | P | 1955 | 78 |
| (Persian Gulf) | 510 | P | P | X | P | 255 | 50 | P | 255 | 50 |
| (Red Sea) | 2000 | P | 700 | 35 | P | 700 | 35 | P | 1700 | 85 |
| Singapore | 193 | 12 | 58 | 30 | P | P | X | P | 26 | 14 |
| Sri Lanka | 1340 | 36 | P | X | P | P | X | P | 305 | 23 |
| Taiwan | 1240 | 1 | P | X | P | P | X | P | 190 | 15 |
| Thailand | 3219 | 2240 | 1805 | 56 | P | P | X | P | 900 | 28 |
| United Arab Emirates | 1448 | 30 | P | X | P | P | X | P | P | X |
| Viet Nam[d] | 3444 | 3200 | P | X | P | P | X | X | X | X |
| Yemen | 523 | X | X | X | P | P | X | P | 160 | 31 |
| Yemen, Dem | 1383 | X | X | X | P | P | X | X | X | X |
| **OCEANIA** | | | | | | | | | | |
| American Samoa[c] | 419 | P | P | X | X | X | X | P | 628 | 150 |
| Australia | 25760 | 11617 | P | X | P | P | X | P | 3000 | 12 |
| Cook Islands[c] | 146 | 0 | 0 | 0 | 0 | 0 | 0 | P | 219 | 150 |
| Federated States of Micronesia[c] | 2610 | P | P | X | P | P | 0 | P | 3915 | 150 |
| Fiji[c j] | 3640 | 433 | P | X | P | P | X | P | 5360 | 150 |
| French Polynesia[c] | 2525 | 0 | 0 | 0 | X | X | X | P | 3788 | 150 |
| Guam | 154 | P | P | X | P | P | X | P | 154 | 100 |
| Hawaii | 22085 | P | P | X | P | P | X | P | P | X |
| Kiribati[c] | 1143 | P | P | X | 0 | 0 | 0 | P | 1715 | 150 |
| Marshall Islands[c] | 1687 | P | P | X | X | X | X | P | 2531 | 150 |
| Nauru | 24 | 0.02 | P | X | X | X | X | P | 30 | 125 |
| New Caledonia[c] | 2254 | 200 | P | X | P | P | X | P | 3381 | 150 |
| New Zealand | 15134 | 198 | P | X | X | X | X | 0 | 0 | 0 |
| Niue[c] | 70 | X | X | X | X | X | X | P | 105 | 150 |
| Northern Marianas | 162 | X | X | X | X | X | X | P | 162 | 100 |
| Palau[c] | 500 | P | P | P | P | X | X | P | 750 | 150 |
| Papua New Guinea | 5152 | 4116 | P | X | P | P | X | P | 3684 | 72 |
| Solomon Islands | 5313 | 642 | P | X | P | P | X | P | P | X |
| Tokelau[c] | 10 | X | X | X | X | X | X | P | 15 | 150 |
| Tonga[c] | 419 | 10 | P | X | X | X | X | P | 628 | 150 |
| Tuvalu[c] | 24 | X | X | X | X | X | X | P | 36 | 150 |
| Vanuatu[c] | 2528 | X | X | X | P | P | X | P | 3792 | 150 |
| Wallis and Futuna[c] | 129 | X | X | X | X | X | X | P | 140 | 150 |
| Western Samoa | 488 | P | P | X | X | X | X | P | P | X |

**Sources:** World Resources Institute; International Institute for Environment and Development.
0 = zero or less than one-half the unit of measure; X = data not available; P = resource present but not quantified.
a = Includes offshore islands.
b = Figure for coral reefs includes banks.
c = Estimate of a 1.5 to 1 ratio of coral reef length to total coastline length based on measurements of the 107 major islands of Fiji and 27 volcanic and coral islands in eastern Polynesia.
d = Excludes offshore islands/islets.
e = Includes three major offshore atolls: Turneffe Islands, Lighthouse Reef, and Glovers Reef.
f = Does not include the Pacific coast seagrass beds.
g = Does not include the Pacific coast coral assemblages.
h = Includes the U.S. and British Virgin Islands except for Virgin Gorda; excludes Netherlands Antilles.
i = Resource data not available for Aruba and Bonaire.
j = Mangrove data for Viti Levu and Vanua Levu.
For additional information, see Sources and Technical Notes.

# Table 10.4 ACCIDENTAL OIL SPILLS, 1973–85

| Year | Number of Tankers Afloat | Accidental Oil Spills | Accidental Spills per Thousand Tankers | Oil Lost (metric tons) |
|---|---|---|---|---|
| 1973 | 3750 | 36 | 9.6 | 84458 |
| 1974 | 3928 | 48 | 12.2 | 67115 |
| 1975 | 4140 | 45 | 10.9 | 188042 |
| 1976 | 4237 | 29 | 6.8 | 204235 |
| 1977 | 4229 | 49 | 11.6 | 213080 |
| 1978 | 4137 | 35 | 8.5 | 260488 |
| 1979 | 3945 | 65 | 16.5 | 723533 |
| 1980 | 3898 | 32 | 8.2 | 135635 |
| 1981 | 3937 | 33 | 8.4 | 45285 |
| 1982 | 3950 | 9 | 2.3 | 1716 |
| 1983 | 3582 | 17 | 4.7 | 387773 |
| 1984 | 3424 | 15 | 4.4 | 24184 |
| 1985[a] | 3285 | 8 | 2.4 | 15000 |

**Source:** Tanker Advisory Center.
a = 1985 data have been estimated by annualizing trends of the first six months of the year.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 10.1 Coastal Areas and Resources, 1972–83

**Sources:** Length of marine coastline: U.S. Central Intelligence Agency, *The World Factbook 1983* (U.S. Government Printing Office, Washington, D.C., 1983). Jurisdictional and economic claims to maritime zones: Office of the Special Representative of the Secretary General for the Law of the Sea, *Law of the Sea Bulletin*, No. 2 (March 1985). Fish catch: U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics 1980* and *1983* (FAO, Rome, 1981 and 1985).

The Office of the Special Representative of the U.N. Secretary General for the Law of the Sea compiles information concerning coastal claims from the U.N. Legislative Series, official gazettes, communications to the Secretary General, legal journals, and other publications. National claims to maritime zones fall into five categories: territorial sea, contiguous zone, exclusive economic zone, fishery zone, and continental shelf claims.

Relevant legislation, decrees, and treaty commitments for 137 of the 141 coastal states are excerpted in the *Law of the Sea Bulletin*, with a note that information for 13 of them was taken from non-authoritative sources and confirmation of their accuracy and completeness was not always possible. The listing is changing as coastal countries seek to secure their claims to maritime resources under the Law of the Sea Convention.

"Territorial sea" commonly refers to an adjacent zone of water, seabed and subsoil, and airspace in which a nation claims sovereignty. The nation's right to enforce its laws and regulations is qualified only by the right of innocent passage of foreign ships. Nations may also claim certain jurisdictional rights in a contiguous zone beyond the territorial sea out to 24 nautical miles; these rights may pertain only to customs, taxation, immigration, and sanitation.

An Exclusive Economic Zone (EEZ) may be established by a nation out to 200 nautical miles to claim all the resources within the zone, including fish and all other living resources, minerals, energy from wind, waves, and tides, etc. Nations may also claim rights to regulate scientific exploration, protect the marine environment, and establish marine terminals and artificial islands.

Continental shelf claims include the exclusive right to explore for and exploit all mineral ores, energy resources, and benthic plants and animals that are found on or beneath the shelf. Claims are based on the distance from the shoreline (e.g. 200 nautical miles) and on the outer limit of the continental margin as defined in the 1982 convention.

International fishery data are under continual revision. The latest *Yearbook of Fishery Statistics* contains what FAO considers the most accurate and up-to-date figures.

Data are provided to the FAO Fisheries Department by national fishery offices and regional commissions. Some countries provide only provisional data for the latest year; others provide no data. If no new data are submitted, FAO uses the previous year's figures or prepares its own estimate based on other information.

Years refer to calendar years except for Antarctic fisheries data, which are for split years (July 1–June 30). Data for Antarctic fisheries are given for the calendar year in which the split year ends.

Catch refers to aquatic plants and animals killed, caught, trapped, collected, bred, or cultivated for commercial, industrial, and subsistence use. Quantities taken in recreational activities are excluded.

This table presents data on nominal catch, which is defined as gross removal (total live weight of fish caught or killed during fishing operations) minus pre-catch losses (total live weight of fish that are not caught but die in fishing operations), minus discarded catch both live and dead (undersized, unsalable, or otherwise undesirable whole fish discarded at the time of capture or shortly afterward), minus utilization and losses prior to landing (consumption by crew, use for bait, spoilage, handling losses), minus unrecorded, rejected, or dumped landings (unrecorded dumping at sea, black market landings, unrecorded quantities landed for home consumption, etc.), minus losses due to dressing, handling, and processing (dumped viscera, heads, and other parts, loss of fluids), plus gains prior to landing (gain of fluid content, addition of liquids or solids during shipboard processing).

### Table 10.2 Marine Fishery Production by Species Group, 1972–83

**Sources:** U.N. Food and Agriculture Organization (FAO), *Yearbook of Fishery Statistics 1978* and *1983* (FAO, Rome, 1980 and 1985).

The FAO divides the world's oceans into 18 distinct marine fisheries.

The FAO organizes catch data by 840 species items, which include species, genera, or families of aquatic plants and animals. These 840 species items are first aggregated into 51 groups of species and then into 9 divisions, recognized as the International Standard Statistical Classification of Aquatic Animals and Plants. The divisions are: freshwater fishes, diadromous fishes, marine fishes, crustaceans, mollusks, whales, seals and other aquatic mammals, miscellaneous aquatic animals, miscellaneous animal products, and aquatic plants.

The species groups shown in Table 10.2 are those with the largest two catches in 1972–73 and 1982–83. In many fisheries, the same two species groups were the leaders for both times; for others, one or both of the top species groups in 1972–73 fell below that level in 1982–83.

### Table 10.3 Tropical Coastal Resources, Early 1980s

**Source:** Nora Berwick, *Tropical Nearshore Resources—Patterns, Processes, Policy, and Impacts* (World Resources Institute/International Institute for Environment and Development, unpublished, 1985).

Tropical coastal resources refer to mangrove, seagrass, and coral reef systems. Areas outside the tropics that have such resources (New Zealand, Japan, Bermuda, the U.S. states along the Gulf of Mexico, etc.) are included.

Figures in the table represent a bounded area where the resources are determined to be important no matter what the density of trees, grass blades, or coral. These delineated areas are quoted from the literature or planimetered from atlases.

Mangroves are defined as tidal forests of salt-tolerant, woody, seed-bearing plants ranging from shrubs to trees. They are found inland along rivers (riverine mangroves), in infrequently flooded inland pools (basin forests), along coasts and lagoons (fringing mangroves), and on low-lying nearshore islands (overwash forests) in the humid tropics.

Seagrass beds are seed-producing marine grasses of varying density with extensive, substrate binding root and rhizome systems.

Coral reefs, an ecosystem composed principally of stony or reef-building corals, are a dominant feature of the shallow coastal marine environment in almost all areas between 25°N and 25 S that are remote from major upwellings or inflows of freshwater.

Table 10.3 is based on estimates from publications, questionnaires completed by experts, and planimetering of maps. The data vary in quality and coverage since a global data base utilizing a systematic quantitative survey of the extent, use, and ecological condition of tropical coastal resources does not exist.

For the many Pacific island countries where there are no data on the extent of reef resources and where the reef is generally longer than the island coastline, the length of the coral reef is estimated at one and one-half times the length of the coastline. This estimate is based on calculations of the coastlines of 107 major islands of the 310 comprising Fiji and of the 27 volcanic and coral islands in eastern Polynesia.

For additional information on coral reefs, the three-volume *Directory of Coral Reefs*, prepared by the Conservation Monitoring Center, International Union for Conservation of Nature and Natural Resources in 1985, presents an overview of the distribution of reefs, an examination of their status and relevant conservation issues and legislation, detailed accounts of established and recommended protected reef areas and of reefs well known for their scientific, fisheries, or tourism value, and a comprehensive bibliography.

## Table 10.4 Accidental Oil Spills, 1973–85

**Source:** Tanker Advisory Center, New York.

The Tanker Advisory Center compiles oil spill accident data from lists of insurance claims and other known accidents maintained by Lloyd's of London and Liverpool Underwriters. Data for the number of tankers afloat are taken from *The Tanker Register*, maintained by H. Clarkson and Co., London.

For 1973–82, data refer to tankers of at least 6,000 metric tons deadweight, and for 1983–85, to tankers of at least 10,000 metric tons deadweight. Vessels carrying liquefied gas are not included.

Spills refer to oil lost during accidents. Oil lost during cleaning and ballasting operations is not included.

# 11. Atmosphere and Climate

The quality of the atmosphere can be measured in three ways: the amounts of pollutants released; the ambient concentration of pollutants in air and precipitation; and the impact pollutants have on humans, other living organisms, materials and buildings, and natural systems, including climate. The tables in this chapter present data on pollutant emissions and ambient concentrations; impact data are not available on a comprehensive basis for most airborne pollutants. The growing amount of data being generated by the Global Environmental Monitoring System (GEMS) has been used in this edition of *World Resources* to highlight urban and regional conditions. Data from GEMS and other sources have been used to examine global atmospheric conditions.

Estimates of the amount of carbon emitted to the atmosphere from the combustion of fossil fuels are presented in Tables 11.1 and 11.2. These estimates, derived from energy production and consumption data, indicate an average annual growth rate in carbon emissions of about 4.4 percent per year from 1950 to 1973 and erratic growth averaging about 1.5 percent per year since 1973. Preliminary data indicate that the carbon emission rate turned sharply upward in 1984.

The geographical pattern of carbon emissions has changed as well. The United States was the source of 44 percent of global carbon emissions in 1950, but only 24 percent in 1983. Japan increased from 2 percent in 1950 to 5 percent in 1983, while China increased from 1 percent of the world total in 1950 to 9 percent in 1983.

The results of carbon dioxide monitoring at stations in remote locations are shown in Table 11.4. Since 1958, the global concentration of carbon dioxide has increased from 315 to 345 parts per million, an increase of about 10 percent. The concentration prior to widespread industrialization and land clearing has been estimated at about 275 parts per million.

Other gases have radiative properties similar to those of carbon dioxide. Chlorofluorocarbons, methane, and nitrous oxide (all of which may modify stratospheric ozone) are of increasing importance in evaluating "greenhouse" effects. Current research indicates that methane concentrations are increasing by about 1 percent per year; nitrous oxide concentrations by about 0.2 percent per year; and chlorofluorocarbon releases, after declining because of regulation and economic recession, are again increasing. The trend in chlorofluorocarbon releases is somewhat uncertain because emissions data are not available for the Soviet Union and several other countries.

Data for urban air quality in 62 cities in 43 countries are given in Tables 11.5 and 11.6. About one fourth of the sites report average annual concentrations of $SO_2$ that are above the upper guideline (40 to 60 micrograms per cubic meter ($\mu g/m^3$)) established by the World Health Organization (WHO) to protect long-term human health. Most of these sites are industrial and commercial and are located in urban centers. The 63 sites that have data for 5 or more years were used to analyze trends. These data indicate that air quality at 54 percent of the sites had improved during the period 1973-80; 30 percent reported no change; and 16 percent reported increased concentrations of $SO_2$.

In Table 11.6 the results of the two principal techniques used to monitor suspended particulate matter—high-volume sampling and smoke-shade sampling—are shown separately. The WHO guidelines to protect long-term health are 60–90 $\mu g/m^3$ for high-volume monitoring and 40–60 $\mu g/m^3$ for smoke-shade monitoring. About 40 percent of all sites are above the upper guideline. Forty-three percent of the sites recorded downward trends; 47 percent recorded no trend; and 10 percent recorded an upward trend.

Missing from this table are data for many large cities that are known to have serious air quality problems. These cities are omitted because they failed to accurately monitor these pollutants for the years indicated or they chose not to participate in the GEMS program. Internationally comparable data for carbon monoxide, photochemical oxidants, and lead—pollutants that can also cause serious health problems in urban areas—are not available.

The latest data on acid and ion deposition at sites around the world are provided in Table 11.7. Monitoring was conducted at locations far from human sources of air pollution to ensure that measured values represent regional or global background conditions, not local problems. A pH reading of approximately 5 or lower usually indicates the presence of excess acidity. The results indicate that even the remote areas of Northern and Central Europe, the eastern portion of North America, and Japan are receptors of anthropogenic acid precipitation.

# Table 11.1 GLOBAL CARBON DIOXIDE EMISSIONS FROM ANTHROPOGENIC SOURCES, 1950–84

| | Carbon Emissions (million metric tons of carbon) | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fossil Fuel Combustion | | | | Other Industrial Sources | |
| | Total | Total | Solid Fuels | Liquid Fuels | Natural Gas | Gas Flaring | Cement Production |
| 1950 | 1639 | 1598 | 1078 | 423 | 97 | 23 | 18 |
| 1951 | 1776 | 1731 | 1137 | 479 | 115 | 24 | 21 |
| 1952 | 1803 | 1755 | 1127 | 504 | 124 | 26 | 22 |
| 1953 | 1848 | 1797 | 1133 | 533 | 131 | 27 | 24 |
| 1954 | 1872 | 1818 | 1123 | 557 | 138 | 27 | 27 |
| 1955 | 2050 | 1990 | 1215 | 625 | 150 | 30 | 30 |
| 1956 | 2185 | 2121 | 1281 | 679 | 161 | 32 | 32 |
| 1957 | 2278 | 2209 | 1317 | 714 | 178 | 35 | 34 |
| 1958 | 2339 | 2268 | 1344 | 732 | 192 | 35 | 36 |
| 1959 | 2470 | 2394 | 1390 | 790 | 214 | 36 | 40 |
| 1960 | 2586 | 2504 | 1419 | 850 | 235 | 39 | 43 |
| 1961 | 2602 | 2515 | 1356 | 905 | 254 | 41 | 46 |
| 1962 | 2709 | 2616 | 1358 | 981 | 277 | 44 | 49 |
| 1963 | 2855 | 2756 | 1403 | 1053 | 300 | 47 | 52 |
| 1964 | 3016 | 2908 | 1442 | 1138 | 328 | 51 | 57 |
| 1965 | 3154 | 3040 | 1467 | 1221 | 352 | 55 | 59 |
| 1966 | 3313 | 3190 | 1485 | 1325 | 380 | 60 | 63 |
| 1967 | 3420 | 3288 | 1454 | 1424 | 410 | 66 | 66 |
| 1968 | 3595 | 3452 | 1455 | 1552 | 445 | 73 | 70 |
| 1969 | 3808 | 3654 | 1493 | 1674 | 487 | 80 | 74 |
| 1970 | 4116 | 3950 | 1595 | 1839 | 516 | 88 | 78 |
| 1971 | 4267 | 4093 | 1594 | 1946 | 553 | 90 | 84 |
| 1972 | 4435 | 4250 | 1612 | 2056 | 582 | 95 | 90 |
| 1973 | 4678 | 4470 | 1622 | 2240 | 608 | 112 | 96 |
| 1974 | 4684 | 4481 | 1620 | 2245 | 616 | 107 | 96 |
| 1975 | 4660 | 4468 | 1715 | 2132 | 621 | 96 | 96 |
| 1976 | 4924 | 4712 | 1754 | 2313 | 645 | 110 | 102 |
| 1977 | 5065 | 4848 | 1812 | 2390 | 646 | 108 | 109 |
| 1978 | 5108 | 4885 | 1828 | 2384 | 673 | 106 | 117 |
| 1979 | 5345 | 5152 | 1899 | 2538 | 715 | 74 | 119 |
| 1980 | 5255 | 5056 | 1924 | 2408 | 724 | 78 | 121 |
| 1981 | 5115 | 4935 | 1928 | 2274 | 733 | 58 | 122 |
| 1982 | 5079 | 4901 | 1983 | 2184 | 734 | 56 | 122 |
| 1983 | 5054 | 4880 | 1985 | 2164 | 731 | 52 | 122 |
| 1984p | 5330 | 5155 | 2103 | 2268 | 784 | 47 | 128 |

**Source:** Institute for Energy Analysis, Oak Ridge Associated Universities.
p = preliminary.
For additional information, see Sources and Technical Notes.

# Table 11.2 CARBON DIOXIDE EMISSIONS, BY COUNTRY AND REGION, 1950, 1965, AND 1983

| | Carbon Emissions from Fossil Fuel Consumption | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1950 (million metric tons of carbon) | | | | | 1965 (million metric tons of carbon) | | | | | 1983 (million metric tons of carbon) | | | | |
| | Solid | Liquid | Gas | Total | Percentage of World Total | Solid | Liquid | Gas | Total | Percentage of World Total | Solid | Liquid | Gas | Total | Percentage of World Total |
| **WORLD** | **1072** | **385** | **96** | **1553** | **100.0** | **1464** | **1118** | **347** | **2929** | **100.0** | **2017** | **2028** | **738** | **4783** | **100.0** |
| North America | 376 | 259 | 88 | 723 | 46.6 | 318 | 447 | 238 | 1003 | 34.2 | 432 | 553 | 260 | 1245 | 26.0 |
| United States | 347 | 245 | 87 | 679 | 43.7 | 301 | 406 | 228 | 935 | 31.9 | 405 | 500 | 233 | 1138 | 23.8 |
| Canada | 29 | 14 | 1 | 44 | 2.8 | 17 | 41 | 10 | 68 | 2.3 | 27 | 53 | 27 | 107 | 2.2 |
| Western Europe | 336 | 40 | 1 | 377 | 24.3 | 358 | 274 | 11 | 643 | 22.0 | 272 | 369 | 112 | 753 | 15.7 |
| United Kingdom | 125 | 11 | X | 136 | 8.8 | 117 | 52 | <1 | 169 | 5.8 | 68 | 45 | 28 | 141 | 2.9 |
| France | 46 | 9 | <1 | 55 | 3.5 | 49 | 42 | 3 | 94 | 3.2 | 30 | 59 | 14 | 103 | 2.2 |
| Germany, Fed Rep | 91 | 2 | X | 93 | 6.0 | 115 | 56 | 1 | 172 | 5.9 | 86 | 68 | 25 | 179 | 3.7 |
| Italy | 7 | 4 | <1 | 11 | 0.7 | 8 | 37 | 4 | 49 | 1.7 | 12 | 65 | 14 | 91 | 1.9 |
| Other | 66 | 15 | <1 | 81 | 5.2 | 68 | 87 | 2 | 157 | 5.4 | 75 | 131 | 32 | 238 | 5.0 |
| Eastern Europe | 250 | 36 | 5 | 291 | 18.7 | 495 | 174 | 79 | 748 | 25.5 | 609 | 405 | 265 | 1279 | 26.7 |
| USSR | 149 | 33 | 3 | 185 | 11.9 | 290 | 151 | 68 | 509 | 17.4 | 355 | 335 | 221 | 911 | 19.0 |
| Poland | 30 | <1 | <1 | 30 | 1.9 | 61 | 4 | 1 | 66 | 2.3 | 97 | 11 | 5 | 113 | 2.4 |
| German Dem Rep | 43 | X | X | 43 | 2.8 | 79 | 3 | X | 82 | 2.8 | 64 | 13 | 5 | 82 | 1.7 |
| Other | 28 | 3 | 2 | 33 | 2.1 | 66 | 16 | 10 | 92 | 3.1 | 93 | 45 | 34 | 172 | 3.6 |
| Pacific | 40 | 5 | X | 45 | 2.9 | 66 | 71 | 1 | 138 | 4.7 | 92 | 173 | 22 | 287 | 6.0 |
| Japan | 26 | 1 | X | 27 | 1.7 | 45 | 55 | 1 | 101 | 3.4 | 61 | 148 | 15 | 224 | 4.7 |
| Other | 14 | 4 | X | 18 | 1.2 | 21 | 16 | X | 37 | 1.3 | 31 | 25 | 7 | 63 | 1.3 |
| Centrally Planned Asia | 22 | <1 | X | 22 | 1.4 | 134 | 11 | 1 | 146 | 5.0 | 403 | 73 | 6 | 482 | 10.1 |
| China | 21 | X | X | 21 | 1.4 | 120 | 10 | 1 | 131 | 4.5 | 365 | 69 | 6 | 440 | 9.2 |
| Other | <1 | X | X | X | X | 14 | 2 | X | 16 | 0.5 | 38 | 4 | X | 42 | 0.9 |
| Developing World | 48 | 45 | 2 | 95 | 6.1 | 93 | 141 | 17 | 251 | 8.6 | 209 | 456 | 73 | 738 | 15.4 |
| Latin America | 6 | 29 | 1 | 36 | 2.3 | 8 | 68 | 11 | 87 | 3.0 | 18 | 171 | 35 | 224 | 4.7 |
| Africa | 19 | 7 | X | 26 | 1.7 | 34 | 20 | 1 | 55 | 1.9 | 66 | 67 | 10 | 143 | 3.0 |
| Middle East | 2 | 2 | X | 4 | 0.3 | 4 | 23 | 2 | 29 | 1.0 | 11 | 89 | 16 | 116 | 2.4 |
| South and Southeast Asia | 20 | 7 | <1 | 27 | 1.7 | 47 | 29 | 3 | 79 | 2.7 | 114 | 129 | 11 | 254 | 5.3 |

**Source:** Institute for Energy Analysis, Oak Ridge Associated Universities.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 11.3 PRODUCTION AND RELEASE OF CHLOROFLUOROCARBONS, 1931–84

| | CFC-11 (thousand metric tons) | | CFC-12 (thousand metric tons) | |
|---|---|---|---|---|
| | Production | Release | Production | Release |
| 1931 | 0.0 | 0.0 | 0.5 | 0.1 |
| 1936 | 0.1 | 0.0 | 1.7 | 0.5 |
| 1941 | 0.3 | 0.1 | 6.3 | 3.0 |
| 1946 | 0.7 | 0.6 | 16.6 | 13.9 |
| 1951 | 9.1 | 7.6 | 36.2 | 32.4 |
| 1956 | 32.5 | 28.7 | 68.7 | 56.1 |
| 1960 | 49.7 | 40.5 | 99.4 | 89.1 |
| 1961 | 60.5 | 52.1 | 108.5 | 99.7 |
| 1962 | 78.1 | 65.4 | 128.1 | 114.5 |
| 1963 | 93.3 | 80.0 | 146.4 | 133.9 |
| 1964 | 111.1 | 95.0 | 170.1 | 155.5 |
| 1965 | 122.8 | 108.3 | 190.1 | 175.4 |
| 1966 | 141.0 | 121.3 | 216.2 | 195.0 |
| 1967 | 159.8 | 137.6 | 242.8 | 219.9 |
| 1968 | 183.1 | 156.8 | 267.5 | 246.5 |
| 1969 | 217.3 | 181.9 | 297.3 | 274.3 |
| 1970 | 238.1 | 206.6 | 321.1 | 299.9 |
| 1971 | 263.2 | 226.9 | 341.6 | 321.8 |
| 1972 | 306.9 | 255.8 | 379.9 | 349.9 |
| 1973 | 349.1 | 292.4 | 423.3 | 387.3 |
| 1974 | 369.7 | 321.4 | 442.8 | 418.6 |
| 1975 | 314.1 | 310.9 | 381.0 | 404.1 |
| 1976 | 339.8 | 316.7 | 410.7 | 390.4 |
| 1977 | 320.5 | 303.9 | 382.8 | 371.2 |
| 1978 | 308.9 | 283.6 | 372.1 | 341.3 |
| 1979 | 289.5 | 263.7 | 357.2 | 337.5 |
| 1980 | 289.6 | 250.8 | 350.2 | 332.5 |
| 1981 | 286.9 | 248.2 | 351.3 | 340.7 |
| 1982 | 271.4 | 239.5 | 328.0 | 337.4 |
| 1983 | 291.7 | 252.8 | 355.3 | 343.3 |
| 1984 | 312.4 | 271.1 | 382.1 | 359.4 |

**Source:** Chemical Manufacturers Association.
0 = zero, or less than 90 metric tons.
For additional information, see Sources and Technical Notes.

# Table 11.4 CARBON DIOXIDE IN THE ATMOSPHERE, 1958–85

Average Annual Concentrations of Carbon Dioxide (parts per million, volume basis)

| | Barrow, Alaska (71°N) | | Mauna Loa, Hawaii (20°N) | | American Samoa (14°S) | | South Pole (90°S) | |
|---|---|---|---|---|---|---|---|---|
| | Concentration | Annual Increase | Concentration | Annual Increase | Concentration | Annual Increase | Concentration | Annual Increase |
| 1958 | X | X | X | X | X | X | 314.6 | X |
| 1959 | X | X | 316.1 | X | X | X | 315.4 | 0.9 |
| 1960 | X | X | 317.0 | 0.9 | X | X | 316.7 | 1.3 |
| 1961 | X | X | 317.7 | 0.7 | X | X | 317.5 | 0.8 |
| 1962 | X | X | 318.6 | 0.9 | X | X | 318.0 | 0.5 |
| 1963 | X | X | 319.1 | 0.5 | X | X | 318.2 | 0.2 |
| 1964 | X | X | 319.6 | 0.5 | X | X | 318.3 | 0.1 |
| 1965 | X | X | 320.4 | 0.8 | X | X | 319.3 | 1.0 |
| 1966 | X | X | 321.1 | 0.7 | X | X | 320.6 | 1.3 |
| 1967 | X | X | 321.8 | 0.7 | X | X | 321.2 | 0.6 |
| 1968 | X | X | 322.8 | 1.0 | X | X | 321.8 | 0.6 |
| 1969 | X | X | 324.2 | 1.4 | X | X | 322.6 | 0.7 |
| 1970 | X | X | 325.5 | 1.3 | X | X | 324.2 | 1.6 |
| 1971 | X | X | 326.5 | 1.0 | X | X | 325.0 | 0.8 |
| 1972 | X | X | 327.7 | 1.3 | X | X | 325.8 | 0.8 |
| 1973 | X | X | 329.7 | 2.0 | X | X | 327.4 | 1.7 |
| 1974 | 332.6 | X | 330.4 | 0.7 | X | X | 328.3 | 0.9 |
| 1975 | 333.4 | 0.8 | 331.0 | 0.6 | X | X | 329.3 | 1.0 |
| 1976 | 333.7 | 0.3 | 332.1 | 1.1 | 331.2 | X | 330.4 | 1.1 |
| 1977 | 334.6 | 0.9 | 333.6 | 1.5 | 332.6 | 1.4 | 331.9 | 1.4 |
| 1978 | 336.7 | 2.1 | 335.2 | 1.6 | X | X | 333.5 | 1.6 |
| 1979 | 337.9 | 1.2 | 336.6 | 1.4 | 336.1 | X | 334.9 | 1.3 |
| 1980 | 339.9 | 2.0 | 338.4 | 1.7 | 338.0 | 1.9 | 336.8 | 1.9 |
| 1981 | 341.7 | 1.8 | 339.5 | 1.1 | 339.2 | 1.2 | 338.1 | 1.3 |
| 1982 | 342.8 | 1.1 | 340.7 | 1.3 | 340.2 | 1.0 | 339.2 | 1.1 |
| 1983 | 343.8 | 1.0 | 342.7 | 2.0 | 341.4 | 1.2 | 341.0 | 1.8 |
| 1984 | 346.0 | 2.2 | 344.4 | 1.7 | 343.0 | 1.6 | 342.4 | 1.4 |
| 1985 | X | X | 345.6 | 1.3 | X | X | X | X |

**Sources:** Scripps Institution of Oceanography; U.S. National Oceanic and Atmospheric Administration.
X = not available.
For additional information, see Sources and Technical Notes.

# Table 11.5 CONCENTRATIONS OF SULFUR DIOXIDE IN URBAN

| | Number of Monitoring Sites | Site-Years | Average Annual Concentration (micrograms per cubic meter) 1973–74 | 1975–76 | 1977–78 | 1979–80 | Average 1973–80 | Range 1973–80 | Trends in Concentration (percent per year) Industrial Site | Commercial Site | Residential Site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **AFRICA** | | | | | | | | | | | |
| Egypt | | | | | | | | | | | |
| Cairo | 3 | 2 | X | 65 | X | X | 65 | 61–69 | X | X | X |
| Ghana | | | | | | | | | | | |
| Accra | 3 | X | X | X | X | X | X | X | X | X | X |
| Kenya | | | | | | | | | | | |
| Nairobi | 2 | X | X | X | X | X | X | X | X | X | X |
| **NORTH AMERICA** | | | | | | | | | | | |
| Canada | | | | | | | | | | | |
| Hamilton | 2 | 10 | X | 53 | 43 | 35 | 42 | 32–57 | X | -10 | -9 |
| Montreal | 3 | 14 | X | 44 | 47 | 37 | 43 | 14–71 | X | -5 | -6 |
| Toronto | 3 | 15 | X | 31 | 27 | 21 | 25 | 18–35 | -7 | -11 | -9 |
| Vancouver | 4 | 22 | 19 | 25 | X | 17 | 20 | 14–29 | 0 | -9 | -2 |
| United States | | | | | | | | | | | |
| Birmingham | 3 | 3 | X | 19 | 17* | X | 18 | 6–32 | X | X | X |
| Chicago | 2 | 2 | X | 20* | X | 48* | 34 | 20–48 | X | X | X |
| Houston | 3 | 9 | X | 3 | 9 | 20* | 9 | 3–20 | X | X | X |
| Los Angeles | 2 | 3 | X | 33 | 40* | X | 35 | 27–40 | X | X | X |
| New York City | 3 | 6 | X | X | X | 59 | 59 | 43–80 | X | X | X |
| St. Louis | 5 | 11 | X | 91 | 68 | 40 | 59 | 25–149 | X | X | X |
| **LATIN AMERICA** | | | | | | | | | | | |
| Brazil | | | | | | | | | | | |
| Rio de Janeiro | 1 | 2 | X | 57* | 128* | X | 93 | 57–128 | X | X | X |
| Sao Paulo | 3 | 15 | X | 100 | 109 | 125 | 114 | 72–153 | +1 | +6 | +10 |
| Chile | | | | | | | | | | | |
| Santiago | 3 | 7 | X | 60 | 66 | 58* | 63 | 48–93 | X | -4 | +1 |
| Colombia | | | | | | | | | | | |
| Bogota | 3 | 2 | X | 18* | 15* | X | 17 | 15–18 | -8 | X | X |
| Cali | 2 | 3 | X | 14 | 10* | X | 12 | 6–21 | X | X | X |
| Medellin | 2 | 3 | X | 25* | 16* | 34* | 25 | 16–34 | X | X | X |
| Cuba | | | | | | | | | | | |
| Havana | 3 | 9 | X | 46 | 38 | X | 41 | 22–66 | X | X | X |
| Peru | | | | | | | | | | | |
| Lima | 3 | 2 | X | 11* | X | 3* | 7 | 3–11 | X | X | X |
| Venezuela | | | | | | | | | | | |
| Caracas | 3 | 6 | X | 14 | 14 | X | 14 | 7–24 | X | X | X |
| **ASIA** | | | | | | | | | | | |
| Hong Kong | | | | | | | | | | | |
| Hong Kong | 3 | 18 | X | 33 | 28 | 45 | 35 | 5–100 | +5 | +70 | +36 |
| India | | | | | | | | | | | |
| Bombay | 3 | 7 | X | X | 51 | 37 | 43 | 20–96 | X | X | X |
| Calcutta | 3 | 21 | 41 | 35 | 40 | 40 | 38 | 17–58 | +2 | 0 | -6 |
| Delhi | 3 | 9 | X | X | 33 | 33 | 33 | 8–58 | X | X | X |
| Iran | | | | | | | | | | | |
| Teheran | 3 | 11 | X | 84* | 50 | 91 | 75 | 40–160 | X | +12 | X |
| Iraq | | | | | | | | | | | |
| Baghdad | 3 | X | X | X | X | X | X | X | X | X | X |
| Israel | | | | | | | | | | | |
| Tel Aviv | 3 | 13 | 29 | 23 | X | 53* | 28 | 16–54 | X | X | X |
| Japan | | | | | | | | | | | |
| Osaka | 4 | 23 | X | 65 | 50 | 38 | 51 | 29–74 | -14 | -14 | -11 |
| Tokyo | 3 | 24 | 65 | 64 | 59 | 54 | 61 | 37–85 | -4 | -4 | -2 |
| Korea, Rep | | | | | | | | | | | |
| Seoul | 3 | X | X | X | X | X | X | X | X | X | X |
| Malaysia | | | | | | | | | | | |
| Kuala Lumpur | 2 | 5 | X | X | 24 | 13 | 18 | 3–43 | X | X | X |
| Pakistan | | | | | | | | | | | |
| Lahore | 2 | X | X | X | X | X | X | X | X | X | X |
| Philippines | | | | | | | | | | | |
| Manila | 3 | 13 | X | 83 | 62 | 66 | 73 | 46–130 | -3 | +1 | -2 |
| Thailand | | | | | | | | | | | |
| Bangkok | 2 | X | X | X | X | X | X | X | X | X | X |

# AREAS, 1973–80

# Table 11.5

| | Number of Monitoring Sites | Site-Years | Average Annual Concentration (micrograms per cubic meter) 1973–74 | 1975–76 | 1977–78 | 1979–80 | Average 1973–80 | Range 1973–80 | Trends in Concentration (percent per year) Industrial Site | Commercial Site | Residential Site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **EUROPE** | | | | | | | | | | | |
| Belgium | | | | | | | | | | | |
| Brussels | 3 | 22 | 111 | 91 | 78 | 77 | 88 | 60–121 | −8 | −4 | −6 |
| Czechoslovakia | | | | | | | | | | | |
| Prague | 3 | 15 | 106 | 106 | 113 | X | 107 | 58–148 | +2 | +1 | +1 |
| Denmark | | | | | | | | | | | |
| Copenhagen | 3 | 10 | X | X | 35 | 23 | 27 | 13–57 | X | X | X |
| Finland | | | | | | | | | | | |
| Helsinki | 3 | 9 | X | X | 27 | 28 | 28 | 24–33 | X | X | X |
| France | | | | | | | | | | | |
| Paris | 4 | 11 | X | X | 105 | 91 | 98 | 77–131 | X | X | X |
| Toulouse | 3 | 7 | X | X | 12 | 7 | 11 | 4–39 | X | X | X |
| Germany, Fed Rep | | | | | | | | | | | |
| Frankfurt | 3 | 11 | 97 | 90 | 79 | 76 | 88 | 74–109 | −8 | −6 | X |
| Greece | | | | | | | | | | | |
| Athens | 3 | 4 | X | X | 35 | 51 | 43 | 30–57 | X | X | X |
| Ireland | | | | | | | | | | | |
| Dublin | 3 | 12 | X | X | 35 | 35 | 35 | 21–56 | X | X | X |
| Italy | | | | | | | | | | | |
| Milan | 2 | 6 | X | X | 208 | 205 | 207 | 167–242 | X | X | X |
| Rome | 3 | 2 | 86 | X | X | X | 86 | 58–114 | X | X | X |
| Netherlands | | | | | | | | | | | |
| Amsterdam | 3 | 21 | 39 | 34 | 28 | 33 | 34 | 21–55 | −4 | −5 | +1 |
| Poland | | | | | | | | | | | |
| Warsaw | 3 | 7 | X | X | 28* | 40 | 39 | 28–47 | X | X | X |
| Wroclaw | 3 | 9 | X | X | 33 | 39 | 37 | 23–46 | X | X | X |
| Portugal | | | | | | | | | | | |
| Lisbon | 2 | X | X | X | X | X | X | X | X | X | X |
| Spain | | | | | | | | | | | |
| Madrid | 3 | 17 | 139 | 100 | 44* | 65 | 100 | 30–193 | −11 | X | −8 |
| Sweden | | | | | | | | | | | |
| Stockholm | 5 | 12 | X | X | 35 | 38 | 36 | 16–60 | 0 | +7 | +2 |
| Switzerland | | | | | | | | | | | |
| Zurich | 1 | X | X | X | X | X | X | X | X | X | X |
| United Kingdom | | | | | | | | | | | |
| Glasgow | 3 | 8 | X | X | 82 | 66 | 76 | 44–94 | X | X | X |
| London | 3 | 18 | 107 | 100 | 78 | 81 | 92 | 56–149 | −10 | −9 | −2 |
| Yugoslavia | | | | | | | | | | | |
| Zagreb | 3 | 24 | 104 | 87 | 73 | 55 | 79 | 33–195 | −8 | −9 | −6 |
| **OCEANIA** | | | | | | | | | | | |
| Australia | | | | | | | | | | | |
| Melbourne | 1 | 5 | X | 14 | 21* | 6 | 12 | 4–21 | X | −17 | X |
| Sydney | 3 | 13 | X | 43 | 40 | 40 | 41 | 19–70 | +1 | −7 | −10 |
| New Zealand | | | | | | | | | | | |
| Auckland | 3 | 12 | X | 12* | 20 | 17 | 18 | 11–25 | +7 | +10 | X |
| Christchurch | 3 | 9 | X | X | 22 | 30 | 27 | 17–37 | X | X | X |

**Sources:** World Health Organization; United Nations Environment Program.
X = incomplete data; * = single year value only.
For additional information, see Sources and Technical Notes.

# Table 11.6 CONCENTRATIONS OF SUSPENDED PARTICULATE

| | Number of Monitoring Sites | Site-Years | Average Annual Concentration (micrograms per cubic meter) 1973–74 | 1975–76 | 1977–78 | 1979–80 | Average 1973–80 | Range 1973–80 | Trends in Concentration (percent per year) Industrial Site | Commercial Site | Residential Site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **High Volume Sampling Method** | | | | | | | | | | | |
| **AFRICA** | | | | | | | | | | | |
| Ghana | | | | | | | | | | | |
| Accra | 3 | X | X | X | X | X | X | X | X | X | X |
| Kenya | | | | | | | | | | | |
| Nairobi | 2 | X | X | X | X | X | X | X | X | X | X |
| **NORTH AMERICA** | | | | | | | | | | | |
| Canada | | | | | | | | | | | |
| Hamilton | 2 | 10 | X | 118 | 109 | 112 | 112 | 99–124 | X | –1 | +1 |
| Montreal | 3 | 14 | X | 84 | 71 | 72 | 73 | 64–92 | X | X | –4 |
| Toronto | 3 | 15 | X | 74 | 71 | 84 | 77 | 66–99 | +7 | +3 | –3 |
| Vancouver | 4 | 21 | 66 | 69 | 73 | 76 | 69 | 52–97 | +5 | 0 | –1 |
| United States | | | | | | | | | | | |
| Birmingham | 4 | 14 | X | 88 | 108 | 77 | 92 | 63–150 | –2 | 0 | X |
| Chicago | 3 | 10 | X | 107 | 110 | 134 | 114 | 68–200 | –7 | X | X |
| Houston | 3 | 10 | X | 83 | 102 | 86 | 95 | 70–115 | X | X | X |
| Los Angeles | 4 | 7 | X | 89 | 103 | X | 97 | 74–124 | X | X | X |
| New York City | 3 | 9 | X | 69 | 72 | 61 | 65 | 51–79 | X | X | X |
| St. Louis | 5 | 16 | 113 | 104 | 87 | X | 102 | 64–144 | –3 | X | X |
| **ASIA** | | | | | | | | | | | |
| India | | | | | | | | | | | |
| Bombay | 3 | 7 | X | X | 279 | 193 | 229 | 136–466 | X | X | X |
| Calcutta | 3 | 24 | 389 | 422 | 364 | 427 | 396 | 292–547 | –3 | –1 | –3 |
| Delhi | 3 | 9 | X | X | 389 | 422 | 411 | 305–535 | X | X | X |
| Indonesia | | | | | | | | | | | |
| Jakarta | 2 | 4 | X | X | X | 209 | 209 | 138–275 | X | X | X |
| Iran | | | | | | | | | | | |
| Teheran | 3 | 11 | X | 330* | 393 | 336 | 356 | 285–459 | –3 | –3 | +2 |
| Iraq | | | | | | | | | | | |
| Baghdad | 3 | X | X | X | X | X | X | X | X | X | X |
| Japan | | | | | | | | | | | |
| Osaka | 4 | 23 | X | 78 | 60 | 59 | 65 | 49–97 | –1 | –11 | –6 |
| Tokyo | 3 | 24 | 66 | 65 | 57 | 58 | 61 | 48–77 | –4 | 0 | –5 |
| Malaysia | | | | | | | | | | | |
| Kuala Lumpur | 2 | 6 | X | X | 122 | 129 | 126 | 79–182 | X | X | X |
| Pakistan | | | | | | | | | | | |
| Lahore | 2 | X | X | X | X | X | X | X | X | X | X |
| Philippines | | | | | | | | | | | |
| Iligan City | 1 | X | X | X | X | X | X | X | X | X | X |
| Manila | 3 | 15 | X | 79 | 91 | 88 | 85 | 71–101 | –3 | X | +7 |
| Thailand | | | | | | | | | | | |
| Bangkok | 3 | 5 | X | X | 162* | 171 | 169 | 162–176 | X | X | X |
| **EUROPE** | | | | | | | | | | | |
| Czechoslovakia | | | | | | | | | | | |
| Prague | 3 | 10 | 137 | 172 | 146 | X | 157 | 124–262 | –4 | –13 | –4 |
| Denmark | | | | | | | | | | | |
| Copenhagen | 3 | 10 | X | X | 32 | 37 | 35 | 27–52 | X | X | X |
| Finland | | | | | | | | | | | |
| Helsinki | 3 | 9 | X | X | 89 | 94 | 92 | 52–163 | X | X | X |
| Germany, Fed Rep | | | | | | | | | | | |
| Frankfurt | 1 | 3 | X | X | 32 | 27* | 30 | 27–33 | X | –9 | X |
| Greece | | | | | | | | | | | |
| Athens | 3 | 3 | X | X | 225 | X | 225 | 204–255 | X | X | X |
| Yugoslavia | | | | | | | | | | | |
| Zagreb | 3 | 23 | 160 | 150 | 151 | 146 | 152 | 127–181 | –2 | –4 | +1 |
| **OCEANIA** | | | | | | | | | | | |
| Australia | | | | | | | | | | | |
| Melbourne | 1 | 6 | X | 27 | 42 | 73* | 42 | 24–73 | X | –2 | X |
| Sydney | 3 | 15 | X | 97 | 92 | 94 | 93 | 72–156 | –7 | +4 | 0 |

# MATTER IN URBAN AREAS, 1973–80

## Table 11.6

| | Number of Monitoring Sites | Site-Years | Average Annual Concentration (micrograms per cubic meter) 1973–74 | 1975–76 | 1977–78 | 1979–80 | Average 1973–80 | Range 1973–80 | Trends in Concentration (percent per year) Industrial Site | Commercial Site | Residential Site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Smoke Sampling Method** | | | | | | | | | | | |
| **AFRICA** | | | | | | | | | | | |
| Egypt | | | | | | | | | | | |
| Cairo | 3 | 4 | X | 67 | 56 | X | 61 | 47–70 | X | X | X |
| **LATIN AMERICA** | | | | | | | | | | | |
| Brazil | | | | | | | | | | | |
| Rio de Janeiro | 1 | 1 | X | 31* | X | X | 31* | X | X | X | X |
| Sao Paulo | 3 | 15 | X | 90 | 77 | 73 | 78 | 61–98 | –5 | –3 | –4 |
| Chile | | | | | | | | | | | |
| Santiago | 3 | 7 | X | 68* | 65 | 100* | 70 | 25–115 | X | +2 | +3 |
| Colombia | | | | | | | | | | | |
| Bogota | 3 | 2 | X | 32* | 24* | X | 28 | 24–32 | X | X | X |
| Cali | 2 | 3 | X | 39 | 27* | X | 35 | 22–55 | X | X | X |
| Medellin | 2 | 3 | X | 44* | 21* | 56* | 40 | 21–56 | X | X | X |
| Cuba | | | | | | | | | | | |
| Havana | 3 | 9 | X | 45 | 47 | X | 46 | 25–61 | X | X | X |
| Peru | | | | | | | | | | | |
| Lima | 3 | 3 | X | 26* | 21* | 6* | 18 | 6–26 | X | X | X |
| Venezuela | | | | | | | | | | | |
| Caracas | 3 | 6 | X | 22 | 22 | X | 22 | 14–31 | X | X | X |
| **ASIA** | | | | | | | | | | | |
| Hong Kong | | | | | | | | | | | |
| Hong Kong | 3 | 18 | X | 59 | 70 | 56 | 62 | 25–120 | –1 | –2 | –1 |
| Iran | | | | | | | | | | | |
| Teheran | 3 | 12 | X | 232* | 171 | 182 | 181 | 90–232 | –2 | –3 | +4 |
| **EUROPE** | | | | | | | | | | | |
| Belgium | | | | | | | | | | | |
| Brussels | 3 | 22 | 29 | 26 | 19 | 19 | 23 | 11–38 | –10 | –6 | –7 |
| Denmark | | | | | | | | | | | |
| Copenhagen | 3 | 12 | X | X | 11 | 15 | 13 | 8–24 | X | X | X |
| France | | | | | | | | | | | |
| Paris | 3 | 11 | X | X | 44 | 45 | 45 | 38–52 | X | X | X |
| Toulouse | 3 | 6 | X | X | 58 | 22 | 46 | 15–179 | X | X | X |
| Ireland | | | | | | | | | | | |
| Dublin | 3 | 12 | X | X | 32 | 22 | 27 | 14–43 | X | X | X |
| Italy | | | | | | | | | | | |
| Rome | 3 | 3 | 31* | 51 | X | X | 44 | 22–80 | X | X | X |
| Poland | | | | | | | | | | | |
| Warsaw | 3 | 7 | X | X | 64* | 49 | 51 | 40–64 | X | X | X |
| Wroclaw | 3 | 9 | X | X | 68 | 61 | 63 | 49–92 | X | X | X |
| Spain | | | | | | | | | | | |
| Madrid | 3 | 16 | 188 | 162 | X | 125 | 160 | 56–307 | –10 | –1 | –6 |
| United Kingdom | | | | | | | | | | | |
| Glasgow | 3 | 8 | X | X | 29 | 30 | 30 | 20–42 | X | X | X |
| London | 3 | 19 | 33 | 34 | 26 | 43 | 33 | 20–84 | +8 | –8 | –4 |
| **OCEANIA** | | | | | | | | | | | |
| New Zealand | | | | | | | | | | | |
| Auckland | 3 | 12 | X | 4* | 5 | 5 | 5 | 4–9 | –5 | 0 | X |
| Christchurch | 3 | 8 | X | X | 23 | 29 | 27 | 19–41 | X | X | –9 |

**Sources:** World Health Organization; United Nations Environment Program.
X = incomplete data; *= single year value only.
For additional information, see Sources and Technical Notes.

# Table 11.7 PRECIPITATION CHEMISTRY MONITORING, 1975–82

| | Average Annual pH | | | | Average Annual Concentration of Sulfate (milligrams per liter) | | | | Average Annual Concentration of Nitrate (milligrams per liter) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975–76 | 1977–78 | 1979–80 | 1981–82 | 1975–76 | 1977–78 | 1979–80 | 1981–82 | 1975–76 | 1977–78 | 1979–80 | 1981–82 |
| **AFRICA** | | | | | | | | | | | | |
| Malawi | | | | | | | | | | | | |
| Nkhome | X | X | X | X | X | X | X | 0.70* | X | X | X | X |
| Tunisia | | | | | | | | | | | | |
| Thala | X | X | 6.7* | X | X | X | 0.47* | X | X | X | 0.01* | X |
| **NORTH AMERICA** | | | | | | | | | | | | |
| Canada | | | | | | | | | | | | |
| Edson | 6.1* | 5.8 | 5.9 | 6.4* | 0.73* | 0.71 | 0.52 | 0.64* | 0.38* | 0.16 | 0.20 | 0.21* |
| Kelowna | X | 6.1 | 5.8 | 5.6* | X | 0.58 | 0.41 | 0.25* | X | 0.30 | 0.38 | 0.31* |
| Hay River | X | X | 6.5* | 6.7* | X | X | 0.73* | 0.65* | X | X | 0.14* | 0.10* |
| Maniwaki | 4.6 | 4.3 | 4.3 | 4.2* | 1.60 | 1.40 | 1.30 | 1.10* | 0.64 | 0.57 | 0.61 | 0.61* |
| Mould Bay | X | 6.5* | 6.2* | 5.5* | X | 1.20 | 0.58* | 0.65* | X | X | 0.13* | 0.05* |
| Mt. Forest | 4.6 | 5.1 | 4.9 | 4.7* | 1.40 | 2.60* | 1.80 | 1.40* | 0.69 | 1.30 | 0.84 | 0.64* |
| Pickle Lake | X | 5.4 | 5.5 | 5.5* | X | 0.70 | 0.61 | 0.99* | X | 0.22 | 0.25 | 0.19* |
| Sable Island | 4.9 | 4.8 | 5.1 | 5.1* | 1.50 | 0.86 | 0.59 | 0.36* | 0.26 | 0.13 | 0.20 | 0.10* |
| Wynyard | X | 6.5 | 6.9 | 6.7* | X | 0.83 | 1.20 | 0.69* | X | 0.51 | 1.00 | 0.35* |
| El Salvador | | | | | | | | | | | | |
| Cerro Verde | 4.7* | 5.5 | 5.1* | X | X | 0.54 | 0.70* | X | X | 0.03* | 0.36* | X |
| United States | | | | | | | | | | | | |
| Alamosa, Colorado | 7.0 | 6.6 | 6.5 | 5.9 | 3.10* | 2.60 | 1.80 | 0.80 | 0.20* | 0.38 | 0.43 | 0.25 |
| Atlantic City, New Jersey | 4.7 | 4.1 | 4.5* | 4.4 | 2.30 | 1.50 | 2.70* | 1.20 | 0.59 | 0.89 | 0.66* | 0.51 |
| Bishop, California | X | X | 6.2 | 6.2 | X | X | 0.50* | 0.69 | X | X | 0.77* | 0.27 |
| Caribou, Maine | 4.9 | 4.9 | 5.2 | 4.8 | 1.20 | 1.60 | 1.10 | 0.65 | 0.29 | 0.41 | 0.31 | 0.26 |
| Glacier National Park, Montana | 5.9 | 5.8 | X | X | 0.39 | 0.72 | X | X | 0.13 | 0.20 | X | X |
| Huron, South Dakota | 6.5* | 6.7* | 6.4 | 6.1 | 0.97* | 0.67* | 0.89 | 0.92 | 0.60* | 1.30* | 0.54 | 0.50 |
| Macon County, North Carolina | 4.7* | 4.5 | 4.5 | X | 0.92* | 0.90 | 0.77 | X | 0.23* | 0.35 | 0.29 | X |
| Mauna Loa, Hawaii | 5.1* | 4.6 | 5.0 | 5.7 | 0.56* | 0.29 | 0.20 | 0.14 | X | 0.15 | 0.07 | 0.03 |
| Meridian, Mississippi | 4.7 | 4.7 | 4.7 | 4.7 | 0.74 | 0.69 | 0.75 | 0.74 | 0.23 | 0.28 | 0.27 | 0.27 |
| Pendleton, Oregon | 5.6 | 5.5 | 5.7 | X | 0.77 | 0.53 | 0.57 | X | 0.33 | 0.43 | 0.68 | X |
| Raleigh, North Carolina | 4.5 | 4.3 | 4.8* | X | 0.94 | 1.00 | 0.87* | X | 0.37 | 0.46 | 0.28* | X |
| Salem, Illinois | 4.7 | 4.3 | 4.7* | 4.4 | 1.60 | 1.10 | 2.60* | 1.20 | 0.49 | 0.46 | 0.90* | 0.47 |
| San Angelo, Texas | X | 6.1* | 6.7 | X | X | 0.72* | 1.60* | X | X | 0.37* | 0.53* | X |
| Tahlequah, Oklahoma | 5.4 | 5.9 | 5.5 | X | 1.30 | 1.10 | 0.97 | X | 0.33 | 0.39 | 0.38 | X |
| Victoria County, Texas | 5.5 | 5.2 | 5.0 | 5.2 | 0.45 | 0.61 | 0.78 | 0.85 | 0.39 | 0.27 | 0.25 | 0.36 |
| **ASIA** | | | | | | | | | | | | |
| France | | | | | | | | | | | | |
| New Amsterdam Island | X | X | X | 5.0 | X | X | X | 0.11 | X | X | X | X |
| India | | | | | | | | | | | | |
| Allahabad | X | X | 7.5 | 7.5 | X | X | X | 0.19 | X | X | 0.18* | 0.70 |
| Jodhpur | X | 8.2* | 7.3 | 7.5 | 1.30* | 0.59 | 0.43* | 0.21 | 0.58* | 0.14 | 0.43 | 0.66 |
| Kodaikanal | X | X | 6.3* | 6.7 | X | 0.26 | 0.06* | 0.17 | X | 0.06 | 0.15 | 0.07 |
| Minicoy | X | 7.1 | 6.8 | X | X | 0.48* | 0.17* | X | X | 0.11* | 0.14 | X |
| Mohanbari | 3.5* | X | 6.5* | 6.7 | 1.00 | 0.67 | 0.49* | 0.26 | 0.59 | 0.94 | 1.10 | 0.77 |
| Nagpur | X | X | 6.4* | 6.4 | X | 0.52* | 0.19* | 0.19 | X | 0.68* | 0.40* | 0.52 |
| Port Blair | 7.6* | X | 6.3* | 6.4 | 0.90 | 0.33 | 0.08* | 0.32 | 0.16 | 0.18 | 0.11 | 0.54 |
| Pune | 7.4 | 7.4 | 6.9 | 6.9 | 1.10 | 0.78 | 0.07* | 0.44 | 0.79 | 0.88 | 0.25 | 0.44 |
| Srinagar | X | 7.7 | 7.3 | 7.0 | X | 0.36 | 0.09* | 0.38 | X | 0.50 | 0.30 | 0.72 |
| Visakapatnam | X | 7.6 | 6.8 | 6.6 | X | 1.40 | 0.96 | 0.49 | X | 0.91 | 0.67 | 1.50 |
| Indonesia | | | | | | | | | | | | |
| Jakarta | X | X | X | 5.8 | X | X | 0.50* | X | X | X | X | 0.57 |
| Japan | | | | | | | | | | | | |
| Ryori | 5.6* | 5.0 | 5.0 | 4.8 | 0.47* | 0.63 | 0.48 | 0.56 | 0.12* | 0.18 | 0.20 | 0.14 |
| Malaysia | | | | | | | | | | | | |
| Cameron Highlands | 5.0* | 5.2 | 5.2 | 5.4 | 1.60* | 0.15* | 0.13* | X | 0.09* | 0.35 | 0.09 | 0.36 |
| **EUROPE** | | | | | | | | | | | | |
| Austria | | | | | | | | | | | | |
| Retz | X | X | 4.7* | X | X | X | 3.50* | X | X | X | 1.10* | X |
| Czechoslovakia | | | | | | | | | | | | |
| Chopok | X | 4.3 | 4.3 | 4.3 | X | 2.40 | 2.40 | 2.10 | X | 0.64 | 0.57 | 0.53 |
| Svratouch | 4.3 | 4.3 | 4.4 | 4.5 | 2.40 | 2.30 | 2.10 | 2.00 | 0.78 | 0.65 | 0.65 | 0.61 |
| Denmark | | | | | | | | | | | | |
| Ejde (Faroes) | 4.9 | 4.9 | 4.7 | X | 1.60 | 2.40 | 1.40 | X | 0.17 | 0.41 | 0.15 | X |
| Finland | | | | | | | | | | | | |
| Jokioinen | 4.4 | 4.3 | 4.4 | 4.2 | 2.30 | 1.50 | 1.70 | 1.40 | 0.56 | 0.61 | 0.54 | 0.58 |
| Sodankyla | 4.7 | 4.6 | 4.7 | 4.6 | 0.65 | 0.58 | 0.56 | 0.59 | 0.23 | 0.27 | 0.20 | 0.21 |
| France | | | | | | | | | | | | |
| Abbeville | X | 4.9 | 5.0 | 5.3 | X | 1.60 | 2.10 | 1.90 | X | 2.00 | 1.60 | 0.81 |
| Carpentras | X | X | 4.9 | 5.4 | X | 1.20 | 1.20 | 1.90 | X | 0.90 | 1.10 | 0.42 |
| Chateauchinon | X | X | 5.0 | 5.0 | X | X | 1.30 | 0.73 | X | X | 0.79 | 0.26 |
| Gourdon | X | 5.1 | 5.1 | 5.3 | X | 1.00 | 0.99 | 1.10 | X | 0.70 | 0.62 | 0.32 |
| Phalsbourg | X | 4.5 | 4.6 | 5.2 | X | 1.30 | 1.30 | 1.50 | X | 2.20 | 1.40 | 0.68 |
| Rostrenen | X | 5.2 | 5.3 | 5.4 | X | 1.20 | 0.70 | 1.00 | X | 0.77 | 0.59 | 0.38 |
| German Dem Rep | | | | | | | | | | | | |
| Neuglobsow | 4.0 | 4.0 | 4.2 | 4.4 | 4.10 | 3.80 | 1.80 | 2.40 | 0.28 | 0.85* | 0.59 | 0.65 |
| Germany, Fed Rep | | | | | | | | | | | | |
| Brotjacklriegel | 4.4 | 4.3 | 4.2 | 4.6* | 1.30* | 1.50 | 1.30 | 2.20* | 0.80* | 0.82* | 0.67 | 0.64* |
| Deuselbach | 4.3* | 4.3 | 4.2 | 4.2* | X | 1.50 | 1.30 | 0.84* | 0.63* | 0.87 | 0.58 | 0.54* |
| Langenbrugge | 4.2 | 4.0 | 4.0 | 4.1* | 1.70* | 2.80 | 2.40 | 1.70* | 0.87 | 1.70 | 1.20 | 0.84* |
| Schauinsland | 4.1 | 4.5 | 4.5 | 4.7* | X | 0.81 | 0.85 | 0.58* | 0.45 | 0.42 | 0.33 | 0.33* |
| Greenland | | | | | | | | | | | | |
| Godhavn | 5.8* | 5.6 | 5.0 | 5.0* | 1.00* | 1.10 | 1.40 | 1.10* | 0.10 | 0.15 | 0.07 | 0.06* |
| Pr. Christians Sund | 5.8* | 5.8* | X | X | 0.97* | 1.50* | X | X | 0.05* | 0.03* | X | X |
| Hungary | | | | | | | | | | | | |
| Kecskemet | 4.6 | 5.0 | 5.4 | 6.1 | 2.10 | 2.50 | 2.50 | 2.70 | 0.91 | 0.73 | 0.89 | 0.71 |
| Ireland | | | | | | | | | | | | |
| Valentia | 5.6 | 5.2 | 5.5 | 5.8 | 1.30 | 1.30 | 0.87 | 0.62 | 0.17 | 0.13 | 0.12 | 0.12 |

## Table 11.7

| | Average Annual pH | | | | Average Annual Concentration of Sulfate (milligrams per liter) | | | | Average Annual Concentration of Nitrate (milligrams per liter) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1975–76 | 1977–78 | 1979–80 | 1981–82 | 1975–76 | 1977–78 | 1979–80 | 1981–82 | 1975–76 | 1977–78 | 1979–80 | 1981–82 |
| Italy | | | | | | | | | | | | |
| Monte Cimone | 5.8 | 5.2 | 5.4 | 4.8 | 1.20 | 0.55 | 0.62 | 0.69 | 0.38 | 0.17 | 0.46 | 0.49 |
| S. Maria de Leuca | 5.6 | 5.9 | 5.5 | 5.1 | 1.40 | 0.76 | 0.73 | 0.48 | 0.10 | 0.24 | 0.51 | 0.40 |
| Trapani | 6.0* | 6.1 | 6.6 | X | 0.91 | 0.84 | 0.76 | X | 0.76 | 0.14 | 0.10 | X |
| Verona | X | X | 4.7 | X | X | X | 0.87 | X | X | X | 0.77 | X |
| Viterbo | 5.2 | 5.3 | 5.2 | 5.0 | 1.20 | 0.74 | 0.58 | 0.61 | 0.07 | 0.12 | 0.64 | 1.20 |
| Netherlands | | | | | | | | | | | | |
| Witteveen | 4.6 | 4.7 | 4.2* | 4.5* | 2.50 | 2.40 | 2.10* | 1.50 | 0.72 | 0.91 | 0.95* | 0.74* |
| Norway | | | | | | | | | | | | |
| As | 4.6 | 4.7 | 4.5 | 5.2* | 2.50 | 2.00 | 2.60 | 1.60* | 0.38 | 0.69 | 1.0 | 0.63* |
| Birkenes | 4.3 | 4.2 | 4.1 | 4.3* | 1.40 | 1:30 | 1.50 | 1.30* | 0.58 | 0.62 | 0.63 | 0.48* |
| Kise | 4.6 | 4.7 | 4.8 | 4.5* | 1.50 | 2.20 | 1.60 | 1.30* | 0.40 | 0.62 | 0.50 | 0.62* |
| Poland | | | | | | | | | | | | |
| Suwalki | 4.7* | 4.7 | 4.7 | 4.5 | 2.70* | 2.20 | 2.10 | 2.10 | 0.80 | 0.66 | 0.70 | 0.66 |
| Portugal | | | | | | | | | | | | |
| Barreiro | X | X | 6.2* | 6.2 | X | X | 1.60* | 1.50 | X | X | 0.22* | 0.26 |
| Faro | X | X | 6.7* | X | X | X | 2.70* | X | X | X | X | X |
| Romania | | | | | | | | | | | | |
| Fundata | X | X | 5.7* | X | X | X | X | X | X | X | X | X |
| Paring | X | X | 5.4* | X | X | X | 2.30* | X | X | X | X | X |
| Rarau | X | X | 5.7* | 5.4 | X | X | 1.50* | 2.50 | X | X | 0.22* | 0.35 |
| Semenic | X | X | 5.0* | 5.7 | X | X | 1.30* | 3.20 | X | X | 0.13* | 0.20 |
| Stina de Vale | X | X | 5.5* | X | X | X | 1.50* | X | X | X | 0.23* | X |
| Turia | X | X | 5.5* | 5.0 | X | X | 2.00* | 2.10 | X | X | 0.28* | 0.28 |
| Sweden | | | | | | | | | | | | |
| Bredkalen | 5.4 | 5.0 | 4.9 | 4.9 | 1.00 | 0.89 | 0.81 | 0.62 | 0.28 | 0.24 | 0.19 | 0.23 |
| Velen | 4.4 | 4.4 | 4.4 | 4.3 | 1.40 | 1.30 | 1.30 | 1.10 | 0.51 | 0.49 | 0.69 | 0.43 |
| Switzerland | | | | | | | | | | | | |
| Jungfraujoch | X | 6.1* | 5.9 | 6.7 | X | 0.25* | 0.45 | 0.33 | X | 0.13* | 0.16 | 0.17 |
| Payerne | X | 5.8* | 5.0 | 5.3 | X | 0.72* | 1.20 | 1.60 | X | 0.38* | 0.65 | 0.71 |
| United Kingdom | | | | | | | | | | | | |
| Eskdalemuir | X | 5.2* | 4.8* | X | X | 1.20* | 1.10* | X | X | 0.23* | 0.30* | X |
| Yugoslavia | | | | | | | | | | | | |
| Lazaropole | 5.1* | 5.3 | 6.2 | X | 2.50* | 2.70 | 1.70 | 2.20* | 0.41* | 0.22 | 0.16 | X |
| Puntijarka | 5.7 | 5.2 | 5.1* | X | 2.20 | 1.80 | 3.30* | X | 1.10 | 0.34 | 0.06* | X |
| **USSR** | | | | | | | | | | | | |
| Irkutsk | X | 6.6* | 6.5* | X | X | 1.50* | 0.99* | 0.77* | X | 0.16* | 0.22* | X |
| Kurgan | 5.4* | 6.3 | 5.9* | X | 1.50* | 2.90 | 3.60* | 3.20* | 0.25* | 0.18* | 0.20* | X |
| Novopjatigorsk | X | 6.4* | 6.6* | X | X | 0.61* | 1.40* | 0.67* | X | 0.15* | 0.24* | X |
| Syktivkar | 5.8 | 5.9 | 5.5* | X | 1.50 | 1.40 | 1.20* | 0.81 | 0.19 | 0.19* | 0.12* | X |
| Turukhansk | 5.5* | 5.7 | 5.9 | X | 0.63* | 0.77 | 0.75* | 1.50* | 0.58* | 0.08 | 0.21* | X |
| **OCEANIA** | | | | | | | | | | | | |
| Australia | | | | | | | | | | | | |
| Cape Grim | X | X | X | X | X | X | X | X | X | X | X | X |
| United States | | | | | | | | | | | | |
| Cape Matatula, Samoa | X | 5.3 | 5.3 | 5.5 | X | 0.26 | 0.17 | 0.18 | X | 0.05 | 0.04 | 0.02 |

**Source:** World Meteorological Organization; U.N. Environment Program.
* = one year's data missing; X = data not available.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 11.1 Global Carbon Dioxide Emissions from Anthropogenic Sources, 1950–84

**Source:** Unpublished data from a database created for the U.S. Department of Energy by R.M. Rotty, Institute for Energy Analysis, Oak Ridge Associated Universities. These figures update Table 14 in: G. Marland and R. M. Rotty, "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1982," *Tellus*, Vol. 36B, pp. 232–261 (1984); and U.S. Department of Energy, "Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1981," Report No. NBB-0036, unpublished.

Carbon emissions can be caused by natural or human factors. Volcanoes emit carbon dioxide, and long-term changes in global vegetation can contribute to, or withdraw from, the atmospheric carbon reservoir. Combustion of fossil fuels adds carbon to the atmosphere, as do gas flaring and cement production. Finally, clearing of forest land for agriculture emits carbon during the burning or decomposition of the biomass. This table presents estimates of anthropogenic emissions of carbon dioxide, but does not include carbon emissions from land clearing or natural processes.

Fossil fuel combustion releases carbon dioxide at rates that vary depending on the amount of each fuel type used (solid, liquid, and gas), the amount that is burned (a fraction is used for non-energy purposes), and the carbon content of the fuel that is burned. The energy database of the U.N. Statistical Office (UNSO) is the source for fuel production and disposition data. These data are reported in energy units: thousand terajoules for gases; metric tons of coal equivalent for solids; and tons of oil equivalent for liquids. National energy production data in physical units (barrels of oil, metric tons of coal, etc.) are converted to equivalent energy units by the UNSO using country- and year-specific conversion factors. (Refer to the Technical Note for Table 8.1 in Chapter 8, "Energy and Minerals," for details.) Since the energy content of a fuel is directly proportional to its carbon content, one can use fuel production data reported in energy units to estimate the amount of carbon dioxide released in combustion.

These data are not always directly usable for carbon budget studies. For example, traditional carbon analyses of coal have correlated carbon content with the gross heating value. (Gross heating value is the amount of heat that could be extracted from fuel combustion if the water vapor in the flue gases were condensed, releasing their latent heat of vaporization.) Recently, however, the UNSO has reported global coal production on a net heating value basis. An adjustment was therefore required to estimate the carbon content of global coal production.

Other adjustments were made in the analysis. For example, it was assumed that approximately 1 percent of the coal used by industry and power plants was unburned (coal dust and char), and a further few percent was converted to non-oxidizing uses (tar, benzene, etc.). Other oxidative reactions of coal (waste bank fires, coal bank fires, methane releases from coal mines, and carbon dioxide emissions from sulfur dioxide scrubbers) are assumed to be of negligible importance in carbon budget modeling.

Refer to the source document for a complete discussion of the data, underlying assumptions, and calculations used to prepare these estimates.

### Table 11.2 Carbon Dioxide Emissions, by Country and Region, 1950, 1965, and 1983

**Source:** Unpublished data from a database created for the U.S. Department of Energy by R.M. Rotty, Institute for Energy Analysis, Oak Ridge Associated Universities.

These estimates of carbon emissions differ from those presented in Table 11.1. The basis for the calculations in Table 11.1 is *global fuel production*, while Table 11.2 is based on *national fuel consumption*. The author believes that the production method is more accurate on a global scale than the consumption method, but it cannot be used to provide estimates of national carbon emissions. The consumption method is more complex. Allowances must be made for international trade, air and sea bunkers, and stock changes. On a global scale, the difference between the two methods is quite small. For example, production data for 1950 yield an estimated carbon emission that is 3 percent higher than the estimate calculated from consumption data. The difference is approximately 4 percent in 1965, and 2 percent in 1983. The author estimates that the margin of error in the calculation of carbon emissions using fuel production data is 6-10 percent.

For further information, refer to the Technical Note for Table 11.1.

### Table 11.3 Production and Release of Chlorofluorocarbons, 1931–84

**Source:** Chemical Manufacturers Association, "Production, Sales, and Calculated Release of CFC–11 and CFC–12 through 1984," Washington, D.C., October 1985.

The Chemical Manufacturers Association contracts with Alexander Grant and Company, Certified Public Accountants, to collect chlorofluorocarbon (CFC) production and sales data from companies based in countries of the Organization for Economic Co-operation and Development (OECD), and in India, Brazil, Venezuela, and Mexico. The data are examined for errors in reporting (double-counting of production by subsidiary and parent companies), inventory changes, and company-to-company sales of CFCs that might be double-counted. Alexander Grant and Company has collected annual production data for CFC–11 and CFC–12 from 1931 to the present.

Producing companies also provide information on the uses of their products: hermetically- and non-hermetically sealed refrigeration uses; open- and closed-cell foam blowing; aerosols; and solvents. Emissions of CFCs are estimated based on use-specific release factors. For example, all CFCs used in solvents, aerosols, and open-cell foam blowing are assumed to be released within six months of production. Refrigeration equipment and closed-cell foam blowing are assumed to have an early release peak due to product defects, with the remainder of the CFCs being released at a rate specific to the type of use. For example, hermetically-sealed refrigeration units are assumed to have an initial processing and filling loss of two percent, and a mean unit lifetime of 12 years. For details on the modelling of CFC releases, refer to R.L. McCarthy, *et al.*, "The Fluorocarbon-Ozone Theory-I," *Atmospheric Environment* Vol. 11, pp. 491–97 (1977).

Data are not available for CFC producers in India (one company reported data in 1983 and 1984), Eastern Europe, the People's Republic of China (PRC), and the Soviet Union. The Soviet Union is thought to be the largest producer of the group. In 1975, it was estimated that the Soviet Union produced about 7,500 metric tons of CFC–11 and 32,000 metric tons of CFC–12. These levels of production were equal to about 2 percent and 10 percent of reported world production of CFC–11 and CFC–12, respectively. More recent authoritative data are not available. Data for India (except one company in 1983 and 1984), Eastern Europe, the PRC, and the Soviet Union are excluded from this table.

### Table 11.4 Carbon Dioxide in the Atmosphere, 1958–85

**Sources:** Data for Mauna Loa and South Pole: C.D. Keeling, Scripps Institution of Oceanography, unpublished data. Data for Barrow and Samoa: U.S. National Oceanic and Atmospheric Administration (NOAA), *Geophysical Monitoring for Climatic Change: Summary Report 1983* (NOAA, Boulder, Colorado, December 1984), and unpublished data.

Data for Mauna Loa, Barrow, and Samoa are collected and analyzed by *in situ* non-dispersive infrared (NDIR) gas analyzers. These instruments monitor the carbon dioxide fraction of air on a continous basis; the data are then aggregated into hourly, daily, and monthly averages. The annual mean is the mean of the monthly averages. Samples are collected at the South Pole in three five-liter flasks twice a month, and are transported to the Scripps Institution of Oceanography for analysis using an NDIR analyzer. The annual mean figures for the South Pole and Mauna Loa were derived from interpolated data; 12 months of data were not available for all years. For details on this procedure, see R.B. Bacastow, *et al.*, "Seasonal Amplitude Increase in Atmospheric $CO_2$ Concentration at Mauna Loa, Hawaii, 1959–1982," *Journal of Geophysical Research*, Vol. 90, p. 529ff (1985).

Annual means disguise large seasonal variations in carbon dioxide concentrations. In April 1974 at Barrow, Alaska the concentration of carbon dioxide was 337.1 parts per million, volume (ppmv); the August mean concentration was 323.5 ppmv, a difference of 13.6 ppmv. This seasonal variation in carbon dioxide concentration is caused by carbon uptake by photosynthetic plants during the summer months.

The data for all monitoring sites undergo revision for several years after they are collected. Data are corrected for several reasons: drift in instrument calibration (analyzers are recalibrated every few years against standards, necessitating revision of data collected between calibrations); hardware changes (moving the analyzer's sampling intake has a significant impact on the data); and perturbations to "background" conditions (e.g. random carbon dioxide emissions from the Mauna Loa volcano must be edited out of the data set). The sum of these revisions is not very large, but it is important to note that data collected since 1983 are provisional, having been collected since the 1982 instrument calibration. Data collected prior to 1983 are largely in final form, although there may be some further editing until "final" values are reached. The latest data may be obtained from the Carbon Dioxide Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Details concerning data collection, revisions, and analysis are contained in the National Oceanic and Atmospheric Administration (NOAA) source and in: C.D. Keeling, *et al.*, "Measurement of the Concentration of Carbon Dioxide at Mauna Loa Observatory, Hawaii," in *Carbon Dioxide Review: 1982*, W.C. Clark, Ed. (Oxford University Press, New York, 1982); C.D. Keeling, *et al.*, "Atmospheric Carbon Dioxide Variations at the South Pole," *Tellus*, Vol. 28, No. 6 (1976); and in a forthcoming article by C.D. Keeling in *Tellus*.

### Table 11.5 Concentrations of Sulfur Dioxide in Urban Areas, 1973–80

**Sources:** World Health Organization (WHO) and U.N. Environment Program (UNEP) *Urban Air Pollution, 1973–80* (WHO, Geneva, 1984); and unpublished data from the Monitoring and Assessment Research Center, University of London, United Kingdom.

Sites are monitoring stations. They are classified by location as center city or suburban, and further classified as industrial, commercial, or residential depending on the predominant use of land surrounding the monitoring station.

A site-year is the number of representative annual average values for all sites in a city. The maximum number is eight for each site for the period covered in the table.

Data for representative sites are submitted by national governments to the Global Environmental Monitoring System (GEMS) maintained by the World Health Organization and the U.N. Environment Program. By 1983, there were 50 countries with approximately 75 cities and 175 sites participating in the project. The coverage of stations and data is substantially better for the northern hemisphere where most large industrial cities are located.

Fewer data are available from developing countries, in part because the GEMS program did not become fully operational until after 1976.

The average is the mean of all representative daily values over the period 1973–80; the range is the high and low values over the same period. Trends have been determined for sites that have five or more years of data, by comparing first and second halves of the monitoring period. Trends are expressed as a percentage change per year.

### Table 11.6 Concentrations of Suspended Particulate Matter in Urban Areas, 1973–80

**Sources:** World Health Organization (WHO) and U.N. Environment Program (UNEP) *Urban Air Pollution, 1973–80* (WHO, Geneva, 1984); and unpublished data from the Monitoring and Assessment Research Center, University of London, United Kingdom.

For a discussion of the urban air pollution project within the Global Environment Monitoring System (GEMS), refer to the Technical Note for Table 11.5.

### Table 11.7 Precipitation Chemistry Monitoring, 1975–82

**Sources:** Data for 1975–80: The World Meteorological Organization (WMO), the U.S Environmental Protection Agency (EPA), the U.S. National Oceanic and Atmospheric Administration (NOAA), and the U.N. Environment Program's Global Environmental Monitoring System (UNEP-GEMS), *Global Atmospheric Background Monitoring for Selected Environmental Parameters: BAPMoN Data for 1975, 1976, 1977, 1978, 1979, and 1980* (National Climate Data Center, Asheville, North Carolina, United States, 1978, 1980, 1981, 1983, and 1984). Data for 1981–82: unpublished data from WMO and the Monitoring and Assessment Research Center (MARC), University of London, United Kingdom.

The WMO Background Air Pollution Monitoring Network (BAPMoN) includes stations worldwide that monitor turbidity, $CO_2$, particulates, and precipitation chemistry at sites far from human sources of air pollution. The goal of the program is to determine current levels of pollution and to identify long-term trends in the concentration of pollutants that may induce climate changes and other effects.

Established in 1970, the network consisted of 115 stations in 43 countries in 1984. Data from 84 stations in 32 countries are reported in the table. Most stations collect data from wet deposition only. Dry deposition can be the predominant source in arid areas, but it is not yet monitored with comparable accuracy.

Annual averages were calculated for sites where at least six monthly observations were recorded.

The data for sulfate concentrations at Sable Island (Canada) and American Samoa have been corrected for sea salt.

Concentrations for $SO_4$ (sulfate) and $NO_3$ (nitrate) are expressed in terms of the sulfur and nitrogen components.

pH is a logarithmic measure of acidity. A pH of 7 indicates neutrality; below 7 is acidic, above 7 is alkaline. A decline in pH from 6.0 to 5.0 is equivalent to a ten-fold increase in acidity.

# 12. Policies and Institutions

The growing concern for environmental conservation and resource management has stimulated the creation of new institutions, laws, and information.

Table 12.1 lists the countries that have ratified some of the most important environmental treaties and conventions of the past 20 years. The list is current as of December 1984. Included are global conventions that deal with the conservation of nature (species and ecosystems), marine pollution, and weapons and the environment.

Conventions that deal with worker safety and consumer products are excluded, as are the hundreds of bilateral and regional conventions that cover transboundary air pollution, weather modification, water use and storage, hunting and fishing rights and quotas, research and monitoring, and other environmental and resource issues for which international agreements are an important aspect of policy.

Regional Seas Conventions, negotiated under the auspices of the United Nations Environment Program (UNEP), have been signed for the Mediterranean Sea, the Persian Gulf, the West and Central African coast, the Southeast Pacific, the Red Sea and Gulf of Aden, and the Wider Caribbean. On March 22, 1985, the Vienna Convention for the Protection of the Ozone Layer was adopted at a conference sponsored by UNEP. It is now undergoing ratification. In addition to formal treaties, UNEP has assisted member countries with Policy Guidelines and a Code of Practice for the Management of Hazardous Wastes (1981); a Provisional Notification Scheme for Banned and Severely Restricted Chemicals (1984); and the Montreal Guidelines for the Protection of the Marine Environment Against Pollution from Land-Based Sources (1985).

Signing and ratifying treaties does not mean countries will abide by the conditions. Environmental conventions have few if any enforcement mechanisms, and countries with the most to lose (or gain) may simply refuse to participate.

Table 12.2 shows countries that have prepared or are preparing environmental and natural resource reports of various kinds. Basically, two kinds of reports have been included: assessments of environmental quality and natural resources, and compendia of statistics. The table is intended to be current as of fall 1985 but, because there is no single clearinghouse for this kind of information, reports from some countries may have been overlooked.

The most ambitious of these reports are the National Conservation Strategies in which various groups within a country, along with the government, attempt to spell out how the resources of the country will be used to support long-term, sustainable development. In 1984, the Conservation for Development Center of the International Union for Conservation of Nature and Natural Resources (IUCN), supported by the U.S. Agency for International Development (U.S. AID), published *A Framework for Sustainable Development* to give advice to and support for countries undertaking the task of preparing National Conservation Strategies.

In the early 1970s, Japan and the United States were the first countries to prepare official state-of-the-environment reports on a periodic basis. By the 1980s, a number of other developed and developing countries (Malaysia, India, the Philippines, and Chile, for example) had published or were in the process of preparing such reports. In August 1985, UNEP published *Guidelines for the Preparation of National State of the Environment Reports*, a checklist of items countries should consider in preparing material for reports.

In 1976, U.S. AID initiated the development of a series of environmental profiles for developing countries. In the first round, 39 draft profiles were prepared and circulated informally to governments and others. U.S. AID is now sponsoring the preparation of Phase II Environmental Profiles, encouraging national governments and indigenous organizations to do the work.

General statistical reports are prepared by almost all governments. In most cases, these reports contain useful data on temperature and precipitation, water resources, agricultural production, population, natural catastrophes, transportation, energy production and consumption, national parks, etc. A few countries have begun to publish separate reports on environmental indicators, statistics, and trends. UNEP, in conjunction with the Monitoring and Assessment Research Center (London), the World Resources Institute (Washington), and the International Institute for Environment and Development (London/Washington), is preparing an environmental data report that will make natural resource and environmental quality data more readily available to users in developing countries.

# Table 12.1 PARTICIPATION IN GLOBAL CONVENTIONS PROTECTING

| | Wetlands (Ramsar) 1971 | World Heritage (Paris) 1972 | Endangered Species (Washington) 1973 | Migratory Species (Bonn) 1979 | Ocean Dumping (London, Mexico, Moscow, Washington) 1972 | Pollution from Ships (London) 1973 | Law of the Sea (Montego Bay) 1982 | Nuclear Test Ban (Moscow) 1963 | Biological and Toxin Weapons (London, Moscow, Washington) 1972 | Regional Seas (UNEP) |
|---|---|---|---|---|---|---|---|---|---|---|
| **WORLD** | | | | | | | | | | |
| **AFRICA** | | | | | | | | | | |
| Algeria | X | X | X | | | | | | | M,ML |
| Angola | | | | | | | | | | |
| Benin | | X | X | | | | | X | X | |
| Botswana | | | X | | | | | X | | |
| Burkina Faso | | | | | | | | | | |
| Burundi | | X | | | | | | | | |
| Cameroon | | X | X | X | | | | | | WCA |
| Cape Verde | | | | | X | | | X | X | |
| Central African Rep | | X | X | | | | | X | | |
| Chad | | | | | | | | X | | |
| Comoros | | | | | | | | | | |
| Congo | | | X | | | | | | X | |
| Djibouti | | | | | | | | | | |
| Egypt | | X | X | X | | | | X | | M,ML,MSP |
| Equatorial Guinea | | | | | | | | | | |
| Ethiopia | | X | | | | | | | X | |
| Gabon | | | | | X | | | X | | |
| Gambia | | | X | | | | X | X | | |
| Ghana | | X | X | | | | X | X | X | |
| Guinea | | X | X | | | | | | | WCA |
| Guinea-Bissau | | | | | | | | X | X | |
| Ivory Coast | | X | | | | | X | X | | WCA |
| Kenya | | | X | | X | X | | X | X | |
| Lesotho | | | | | | | | | X | |
| Liberia | | | X | | | | | X | | |
| Libya | | X | | | X | | | X | | M |
| Madagascar | | X | X | | | | | X | | |
| Malawi | | X | X | | | | | X | | |
| Mali | | X | | | | | | | | |
| Mauritania | X | X | | | | | | X | | |
| Mauritius | | | X | | | | | X | X | |
| Morocco | X | X | X | | X | | | X | | M |
| Mozambique | | X | X | | | | | | | |
| Niger | | X | X | X | | | | X | X | |
| Nigeria | | X | X | | X | | | X | X | WCA |
| Rwanda | | | X | | | | | X | X | |
| Senegal | X | X | X | | | | | X | X | WCA |
| Sierra Leone | | | | | | | | X | X | |
| Somalia | | | | | | | | | | |
| South Africa | X | | X | | X | | | X | X | |
| Sudan | | X | X | | | | | X | | R |
| Swaziland | | | | | | | | X | | |
| Tanzania, United Rep | | X | X | | | | | X | | |
| Togo | | | X | | | | | X | X | WCA |
| Tunisia | X | X | X | | X | X | | X | X | M,ML,MSP |
| Uganda | | | | | | | | X | | |
| Zaire | | X | X | | X | | | X | X | |
| Zambia | | X | X | | | | | X | | |
| Zimbabwe | | X | X | | | | X | | | |
| **NORTH AMERICA** | | | | | | | | | | |
| Barbados | | | | | | | | | X | |
| Canada | X | X | X | | X | | | X | X | |
| Costa Rica | | X | X | | | | | X | X | |
| Cuba | | X | | | X | | X | | X | |
| Dominican Rep | | | | | X | | | X | X | |
| El Salvador | | | | | | | | X | | |
| Guatemala | | X | X | | X | | | X | X | |
| Haiti | | X | | | X | | | | | |
| Honduras | | X | X | | X | | | X | X | |
| Jamaica | | X | | | | | X | | X | |
| Mexico | | X | | | X | | X | X | X | C |
| Nicaragua | | X | X | | | | | X | X | |
| Panama | | X | X | | X | | | X | X | |
| Trinidad and Tobago | | | X | | | | | X | | |
| United States | | X | X | | X | | | X | | C |
| **SOUTH AMERICA** | | | | | | | | | | |
| Argentina | | X | X | | X | | | | X | |
| Bolivia | | X | X | | | | | X | X | |
| Brazil | | X | X | | X | | | X | X | |
| Chile | X | X | X | X | X | | | X | X | |
| Colombia | | X | X | | | X | | | | |
| Ecuador | | X | X | | | | | X | | SEP |
| Guyana | | X | X | | | | | | | |
| Paraguay | | | X | | | | | | X | |
| Peru | | X | X | | | X | | X | | |
| Suriname | | | X | | X | | | X | | |
| Uruguay | X | | X | | | X | | X | X | |
| Venezuela | | | X | | | | | X | X | |

# THE ENVIRONMENT, 1984

## Table 12.1

| | Wetlands (Ramsar) 1971 | World Heritage (Paris) 1972 | Endangered Species (Washington) 1973 | Migratory Species (Bonn) 1979 | Ocean Dumping (London, Mexico, Moscow, Washington) 1972 | Pollution from Ships (London) 1973 | Law of the Sea (Montego Bay) 1982 | Nuclear Test Ban (Moscow) 1963 | Biological and Toxin Weapons (London, Moscow, Washington) 1972 | Regional Seas (UNEP) |
|---|---|---|---|---|---|---|---|---|---|---|
| **ASIA** | | | | | | | | | | |
| Afghanistan | | X | | | X | | | X | X | |
| Bahrain | | | | | | | | | | P |
| Bangladesh | | X | X | | | | | | | |
| Bhutan | | | | | | | | X | X | |
| Burma | | | | | | | | X | | |
| China | | | X | | | | | X | X | |
| Cyprus | | | | | | | | | | M |
| India | X | X | X | X | | | | X | X | |
| Indonesia | | | X | | | | | X | | |
| Iran | X | X | X | | | | | X | X | P |
| Iraq | | X | | | | | | X | | P |
| Israel | | | X | X | | | | X | | M |
| Japan | X | | X | | X | | | X | X | |
| Jordan | X | X | X | | X | X | | X | X | |
| Kampuchea, Dem | | | | | | | | | X | |
| Korea, Dem People's Rep | | | | | | | | | | |
| Korea, Rep | | | | | | | | X | | |
| Kuwait | | | | | | | | X | X | P |
| Lao People's Dem Rep | | | | | | | | X | X | |
| Lebanon | | X | | | | | | X | X | M |
| Malaysia | | | X | | | | | X | | |
| Mongolia | | | | | | | | X | X | |
| Nepal | | X | X | | | | | X | | |
| Oman | | X | | | X | | | | | P |
| Pakistan | X | X | X | | | | | | X | |
| Philippines | | | X | | X | | X | X | X | |
| Qatar | | X | | | | | | | X | P |
| Saudi Arabia | | X | | | | | | | X | P |
| Singapore | | | | | | | | X | X | |
| Sri Lanka | | X | X | | | | | X | | |
| Syrian Arab Rep | | X | | | | | | X | | M |
| Thailand | | | X | | | | | X | X | |
| Turkey | | X | | | | | | X | X | M,ML |
| United Arab Emirates | | | X | | X | | | | | P |
| Viet Nam | | | | | | | | | X | |
| Yemen | | X | | | | X | | | | R |
| Yemen, Dem | | X | | | | | | X | X | |
| **EUROPE** | | | | | | | | | | |
| Albania | | | | | | | | | | |
| Austria | X | | X | | | | | X | X | |
| Belgium | | | X | | | X | | X | X | |
| Bulgaria | X | X | | | | | | X | X | |
| Czechoslovakia | | | | | | | | X | X | |
| Denmark | X | X | X | X | X | | | X | X | |
| Finland | X | | X | | X | | | X | X | |
| France | | X | X | | X | | | | | M,ML |
| German Dem Rep | X | | X | | X | | | X | X | |
| Germany, Fed Rep | X | X | X | X | X | X | | X | X | |
| Greece | X | X | | | X | | | X | X | M |
| Hungary | X | | | X | X | X | | X | X | |
| Ireland | | | | X | X | | | X | X | |
| Italy | X | X | X | X | X | X | | X | X | M,ML,MSP |
| Luxembourg | | X | | X | | | | X | X | |
| Malta | | X | | | | | | X | X | M |
| Netherlands | X | | X | X | X | | | X | X | C |
| Norway | X | X | X | | X | X | | X | X | |
| Poland | X | X | | | X | | | X | X | |
| Portugal | X | X | X | X | X | | | | X | |
| Romania | | | | | | | | X | X | |
| Spain | X | X | | X | X | | | X | X | M,ML |
| Sweden | X | | X | X | X | | | X | X | |
| Switzerland | X | X | X | | X | | | X | X | |
| United Kingdom | X | X | X | | X | X | | X | X | |
| Yugoslavia | X | X | | | X | X | | X | X | M |
| **USSR** | X | | X | | X | | | X | X | |
| **OCEANIA** | | | | | | | | | | |
| Australia | X | X | X | | | | | X | X | |
| Fiji | | | | | | | X | X | X | |
| New Zealand | X | | | | X | | | X | X | |
| Papua New Guinea | | | X | | X | | | X | X | |
| Solomon Islands | | | | | X | | | | X | |
| **ANTARCTICA** | | | | | | | | | | |

**Source:** U. N. Environment Program.
X = ratified member; other symbols refer to specific Regional Sea conventions, described in the Sources and Technical Notes.
For additional information, see Sources and Technical Notes.

# Table 12.2 NATIONAL AND REGIONAL SOURCES OF

| | National Conservation Strategy | U.S. AID Phase I Draft Environmental Profile | U.S. AID Phase II Environmental Profile | State of the Environment Report | U.S. Foreign Disaster Assistance Country Profile | Country Statistical Yearbook | Environmental Statistical Report | Regional Report on Resources and the Environment | INFOTERRA Participant |
|---|---|---|---|---|---|---|---|---|---|
| **WORLD** | | | | | | | | | |
| **AFRICA** | | | | | | | | | |
| Algeria | | | | | | P | | | I |
| Angola | | | | | | P | | | |
| Benin | | | | | | | | | I |
| Botswana | U | | | | | P | | | I |
| Burkina Faso | | P80 | P | U(G) | P82 | P | | | I |
| Burundi | | P81 | | | | P | | P84(NGO) | I |
| Cameroon | | P81 | | | | P | | | I |
| Cape Verde | | P80 | | | P84 | P | | | I |
| Central African Rep | | | | | | P | | | I |
| Chad | | | | | P82 | P | | | |
| Comoros | | | | | P84 | | | | I |
| Congo | | | | | | P | | | I |
| Djibouti | | | | | P81 | P | | | |
| Egypt | | P80 | | | | P | | | I |
| Equatorial Guinea | | | | | | P | | | |
| Ethiopia | | | | | P81 | P | | | I |
| Gabon | | | | | | P | | | I |
| Gambia | | P | | | P82 | P | | | I |
| Ghana | | P80 | | | P85 | P | | | I |
| Guinea | D | P83 | | | | | | | I |
| Guinea-Bissau | D | | | | | P | | | I |
| Ivory Coast | D | | | | | P | | | I |
| Kenya | | | | | P81 | P | | P84(NGO) | I |
| Lesotho | | P82 | | | | P | | | |
| Liberia | | P80 | | | | P | | | I |
| Libya | | | | | | P | | | I |
| Madagascar | P84 | | | | P84 | P | | | I |
| Malawi | | P82 | | | | P | | | I |
| Mali | | P80 | | | P83* | P | | | I |
| Mauritania | | P79 | P | | P84 | P | | | I |
| Mauritius | | | | | P84 | P | | | I |
| Morocco | | P81 | | | | P | | | I |
| Mozambique | | | | | P* | P | | | |
| Niger | | P80 | | | P85 | P | | | I |
| Nigeria | | | | | | P | | | I |
| Rwanda | | P81 | | | | P | | P84(NGO) | I |
| Senegal | U | P80 | | | P82 | P | | | I |
| Sierra Leone | D | | | | | P | | | |
| Somalia | | | | | P81 | P | | | I |
| South Africa | P80 | | | | | P | | | |
| Sudan | | P | | U(G) | P81 | P | | | I |
| Swaziland | | P80 | | | | P | | | |
| Tanzania, United Rep | | | | | P81 | P | | P84(NGO) | I |
| Togo | | | | | | P | | | I |
| Tunisia | | P80 | | | | P | | | I |
| Uganda | U | P82 | | | P81 | P | | P84(NGO) | I |
| Zaire | D | P | P | | P82 | P | | | I |
| Zambia | P85 | P82 | | | P81 | P | | | I |
| Zimbabwe | U | P82 | | | | P | | | |
| **NORTH AMERICA** | | | | | | | | | |
| Barbados | | P | | | P82 | P | | P82(NGO) | I |
| Canada | D | | | U(G)85 | | P | U85 | P79,85(IGO) | I |
| Costa Rica | D | P | P | | P82 | P | | P82(NGO)/U85(NGO) | I |
| Cuba | | | | | | P | | P82(NGO) | |
| Dominican Rep | | | P | | P84 | P | | P82(NGO) | |
| El Salvador | | P82 | P | | P84 | P | | P82(NGO)/U85(NGO) | I |
| Guatemala | | P81 | P | | P82 | P | | P82(NGO)/U85(NGO) | I |
| Haiti | | P79 | P85 | | P84 | P | | P82(NGO) | |
| Honduras | | P81 | P | | P81 | P | | P82(NGO)/U85(NGO) | I |
| Jamaica | | P | U | | P83 | P | | P82(NGO) | I |
| Mexico | D | | | | | P | | P82(NGO) | I |
| Nicaragua | | P81 | | | P81 | P | | P82(NGO)/U85(NGO) | |
| Panama | | | P | | | P | | P82(NGO)/U85(NGO) | I |
| Trinidad and Tobago | | | | | P82 | P | | P82(NGO) | |
| United States | | | | a | | P | P79 | P79,85(IGO) | I |
| **SOUTH AMERICA** | | | | | | | | | |
| Argentina | D | | | | | P | | P82(NGO) | I |
| Bolivia | | P80 | P | | P84 | P | | P82(NGO) | I |
| Brazil | D | | | | | P | | P82(NGO) | I |
| Chile | | | | P(NGO)85 | P80* | P | | P82(NGO) | I |
| Colombia | | | | | | P | | P82(NGO) | I |
| Ecuador | | P79 | P | | P83 | P | | P82(NGO) | I |
| Guyana | | P | | | P82 | P | | P82(NGO) | I |
| Paraguay | | | P | | | P | | P82(NGO) | I |
| Peru | | P79 | U | | P83 | P | | P82(NGO) | I |
| Suriname | | | | | | | | | |
| Uruguay | | | | | | P | | P82(NGO) | I |
| Venezuela | D | | | | | P | | P82(NGO) | I |

# ENVIRONMENTAL INFORMATION, 1970–85

## Table 12.2

| | National Conservation Strategy | U.S. AID Phase I Draft Environmental Profile | U.S. AID Phase II Environmental Profile | State of the Environment Report | U.S. Foreign Disaster Assistance Country Profile | Country Statistical Yearbook | Environmental Statistical Report | Regional Report on Resources and the Environment | INFOTERRA Participant |
|---|---|---|---|---|---|---|---|---|---|
| **ASIA** | | | | | | | | | |
| Afghanistan | | | | | | P | | P84(IGO) | |
| Bahrain | | | | | | P | | | I |
| Bangladesh | D | P80 | | | P83 | P | | P84(IGO) | I |
| Bhutan | | | | | | | | P84(IGO) | |
| Burma | | P82 | | | P80 | P | | P84(IGO) | |
| China | D | | | U(IGO)83 | | P | | P84(IGO) | I |
| Cyprus | | | | | | P | | | I |
| India | D | P80 | | P(NGO)85 | P83 | P | | P84(IGO) | I |
| Indonesia | D | P | | | P83 | P | | P84(IGO) | I |
| Iran | | | | | | P | | P84(IGO) | |
| Iraq | | | | | | P | | | I |
| Israel | | | | | | P | | | I |
| Japan | | | | P(G)70-85 | | P | P80 | P79,85(IGO)/P84(IGO) | I |
| Jordan | U | P79 | | | | P | | | I |
| Kampuchea, Dem | | | | | | P | | P84(IGO) | |
| Korea, Dem People's Rep | | | | | | | | P84(IGO) | |
| Korea, Rep | | | | | | P | | P84(IGO) | I |
| Kuwait | | | | | | P | | | I |
| Lao People's Dem Rep | | | | | | P | | P84(IGO) | |
| Lebanon | | | | | | P | | | I |
| Malaysia | D | | | P(NGO)84 | | P | | P84(IGO) | I |
| Mongolia | | | | | | P | | P84(IGO) | I |
| Nepal | U | P79 | | | P83 | P | | P84(IGO) | I |
| Oman | D | P81 | | | | P | | | I |
| Pakistan | D | P81 | | | P83 | P | P84 | P84(IGO) | I |
| Philippines | U | P80 | | P(G)83 | P82 | P | P79 | P84(IGO) | I |
| Qatar | | | | | | P | | | I |
| Saudi Arabia | | | | U(G)84 | | P | | | I |
| Singapore | | | | | | P | | P84(IGO) | |
| Sri Lanka | U | P78 | P | | P83 | P | | P84(IGO) | I |
| Syrian Arab Rep | | P81 | | | | P | | | I |
| Thailand | D | P79 | | | | P | | P84(IGO) | I |
| Turkey | | | P | P(NGO) | P82 | P | | P79,85(IGO) | I |
| United Arab Emirates | | | | | | P | | | I |
| Viet Nam | P85 | | | | | P | | P84(IGO) | I |
| Yemen | | P82 | | | | P | | | I |
| Yemen, Dem | | | | | | P | | | |
| **EUROPE** | | | | | | | | | |
| Albania | | | | | | P | | | |
| Austria | | | | P(G) | | P | P82 | P79,85(IGO) | I |
| Belgium | | | | P(G)79 | | P | | P79,85(IGO) | I |
| Bulgaria | | | | | | P | | | I |
| Czechoslovakia | D | | | | | P | | | I |
| Denmark | | | | P(G) | | P | | P79,85(IGO) | I |
| Finland | | | | P(G)85 | | P | P80 | P79,85(IGO) | I |
| France | D | | | P(G)78–85 | | P | P83 | P79,85(IGO) | I |
| German Dem Rep | | | | | | P | | | I |
| Germany, Fed Rep | | | | P(NGO) | | P | P79 | P79,85(IGO) | I |
| Greece | D | | | | | P | | P79,85(IGO) | I |
| Hungary | | | | | | P | P81 | | I |
| Ireland | | | | P(G)85 | | P | | P79,85(IGO) | I |
| Italy | U | | | P(G) | | P | P | P79,85(IGO) | I |
| Luxembourg | | | | P(G) | | P | | P79,85(IGO) | |
| Malta | | | | | | P | | | I |
| Netherlands | D | | | P(G) | | P | P80 | P79,85(IGO) | I |
| Norway | D | | | | | P | P83 | P79,85(IGO) | I |
| Poland | | | | P(G)85 | | P | P79 | | I |
| Portugal | | | | | | P | | P79,85(IGO) | I |
| Romania | | | | | | P | | | I |
| Spain | D | | | P(G) | | P | | P79,85(IGO) | I |
| Sweden | | | | P(G)83 | | P | P81 | P79,85(IGO) | I |
| Switzerland | | | | | | P | | P79,85(IGO) | I |
| United Kingdom | P83 | | | | | P | P80 | P79,85(IGO) | I |
| Yugoslavia | | | | P(G)80 | | P | P79 | P79,85(IGO) | I |
| **USSR** | | | | | | P | | | I |
| **OCEANIA** | | | | | | | | | |
| Australia | P83 | | | P(G)85 | | P | P83 | P79,85(IGO)/P84(IGO) | I |
| Fiji | D | | | | P80 | P | | P84(IGO) | I |
| New Zealand | P85 | | | | | P | | P79,85(IGO)/P84(IGO) | I |
| Papua New Guinea | | | | | P85 | P | | P84(IGO) | |
| Solomon Islands | | | | | | P | | P84(IGO) | |
| **ANTARCTICA** | | | | | | | | | |

**Sources:** World Resources Institute, International Institute for Environment and Development.
P = published; U = unpublished; D = under discussion; * = publication being updated; IGO = prepared by an international governmental organization; NGO = prepared by a non-governmental organization; G = prepared by a governmental organization; I = participant in the UNEP INFOTERRA program; a = P(G)70-83/P(NGO)82,84.
For additional information, see Sources and Technical Notes.

## Sources and Technical Notes

### Table 12.1 Participation in Global Conventions Protecting the Environment, 1984

**Source:** United Nations Environment Program (UNEP), "Environmental Law in the United Nations Environment Programme" (UNEP, Nairobi, 1985).

As requested by the U.N. General Assembly, the UNEP Environmental Law Unit maintains a *Register of International Treaties and other Agreements in the Field of the Environment,* which summarizes the content and current membership status of more than 100 multilateral conventions and protocols. The Register is updated periodically and copies are sent to member states for review. One of the principal aims of this activity is to promote the wider acceptance and use of existing international legal instruments by governments. The complete titles of the conventions and treaties are:

1. Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, 1971);
2. Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972);
3. Convention on International Trade in Endangered Species of Wild Fauna and Flora (Washington, 1973);
4. Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979);
5. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, Mexico, Moscow, Washington, 1972);
6. International Convention for the Prevention of Pollution from Ships (London, 1973);
7. United Nations Convention on the Law of the Sea (Montego Bay, 1982);
8. Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water (Moscow, 1963);
9. Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons, and on their Destruction (London, Moscow, Washington, 1972).

Some of the symbols used to indicate ratification of a Regional Sea Convention actually indicate ratification of several related conventions and protocols.

The full titles of Regional Seas Conventions and the letters used in the table to abbreviate them are listed below.

M = Convention for the Protection of the Mediterranean Sea Against Pollution (1976). Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft (1976). Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency (1976).

ML = Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-based Sources (1980).

MSP = Protocol Concerning Mediterranean Specially Protected Areas (1982).

WCA= Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (1981). Protocol Concerning Co-operation in Combating Pollution in Cases of Emergency (1981).

R = Regional Convention for the Conservation of the Red Sea and Gulf of Aden (1982). Protocol Concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency (1982).

SEP = Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (1981). Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Oil and Other Harmful Substances in Cases of Emergency (1981). Supplementary Protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Oil and Other Harmful Substances in Cases of Emergency (1983). Protocol for the Protection of the South-East Pacific Against Pollution from Land-based Sources (1983).

C = Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1983). Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region (1983).

### Table 12.2 National and Regional Sources of Environmental Information, 1970-85

**Sources:** National Conservation Strategies: International Union for Conservation of Nature and Natural Resources (IUCN), *National Conservation Strategies: A Report to Development Assistance Agencies on Progress and Priorities in Planning for Sustainable Development.* (IUCN, Gland, Switzerland, June 1983), draft; *World Conservation Strategy in Action,* (IUCN Bulletin Supplement No. 4), September 1985, p. 8.

U.S. AID Phase I Draft Environmental Profiles: List from the Office of Arid Land Studies, University of Arizona, January 1985.

U.S. AID Phase II Environmental Profiles: List from the International Institute for Environment and Development, October 1985; U.S. Agency for International Development and U.S. National Park Service, *Natural Resource Technical Bulletin,* No. 5, Spring 1984.

State-of-the-Environment Reports: Various sources.

Foreign Disaster Assistance Reports: List from the Office of Foreign Disaster Assistance, U.S. AID, November, 1985.

Statistical Yearbooks: U.N. Statistical Office, *Directory of Environment Statistics,* (United Nations, New York, 1983), and other sources.

Environmental Statistical Reports: List from the U.N. Statistical Office, November 1985, and other sources.

Regional Reports on Natural Resources and the Environment: Organization for Economic Co-operation and Development, *State of the Environment 1985* (OECD, Paris, 1985); U.N. Economic and Social Commission for Asia and the Pacific, *State of the Environment in Asia and the Pacific* (United Nations, Bangkok, 1984); Program for International Development, *Renewable Resource Trends in East Africa,* (Clark University, Worcester, Massachusetts, 1984); M.J. Dourojeanni, *Renewable Natural Resources of Latin America and the Caribbean, Situation and Trends* (World Wildlife Fund, Washington, D.C., 1982); International Institute for Environment and Development, *Natural Resources and Economic Development in Central America* (International Institute for Environment and Development (IIED), Washington D.C., 1985) draft.

INFOTERRA Participants: List provided by UNEP, September 1985. INFOTERRA, the International Referral System for Sources of Environmental Information, is a network of national focal points—centers of information—established by UNEP for the exchange of environmental information. At present, INFOTERRA focal points are located in 126 countries, including 103 developing countries. The system handles about 750 inquiries per month; most of these concern pollution control technology, chemicals, atmosphere and climate, environmental monitoring, and management and planning.

National Conservation Strategy reports refer to documents that have been prepared in support of the program. Some are endorsed by the national governments; others are not. Countries that are classified "D" (under discussion) are those that have adopted or endorsed a National Conservation Strategy plan of action or have some other involvement with the program. They may or may not produce a published document. For more detailed information on the status of National Conservation Strategies, see past issues of the *IUCN Bulletin Supplement.*

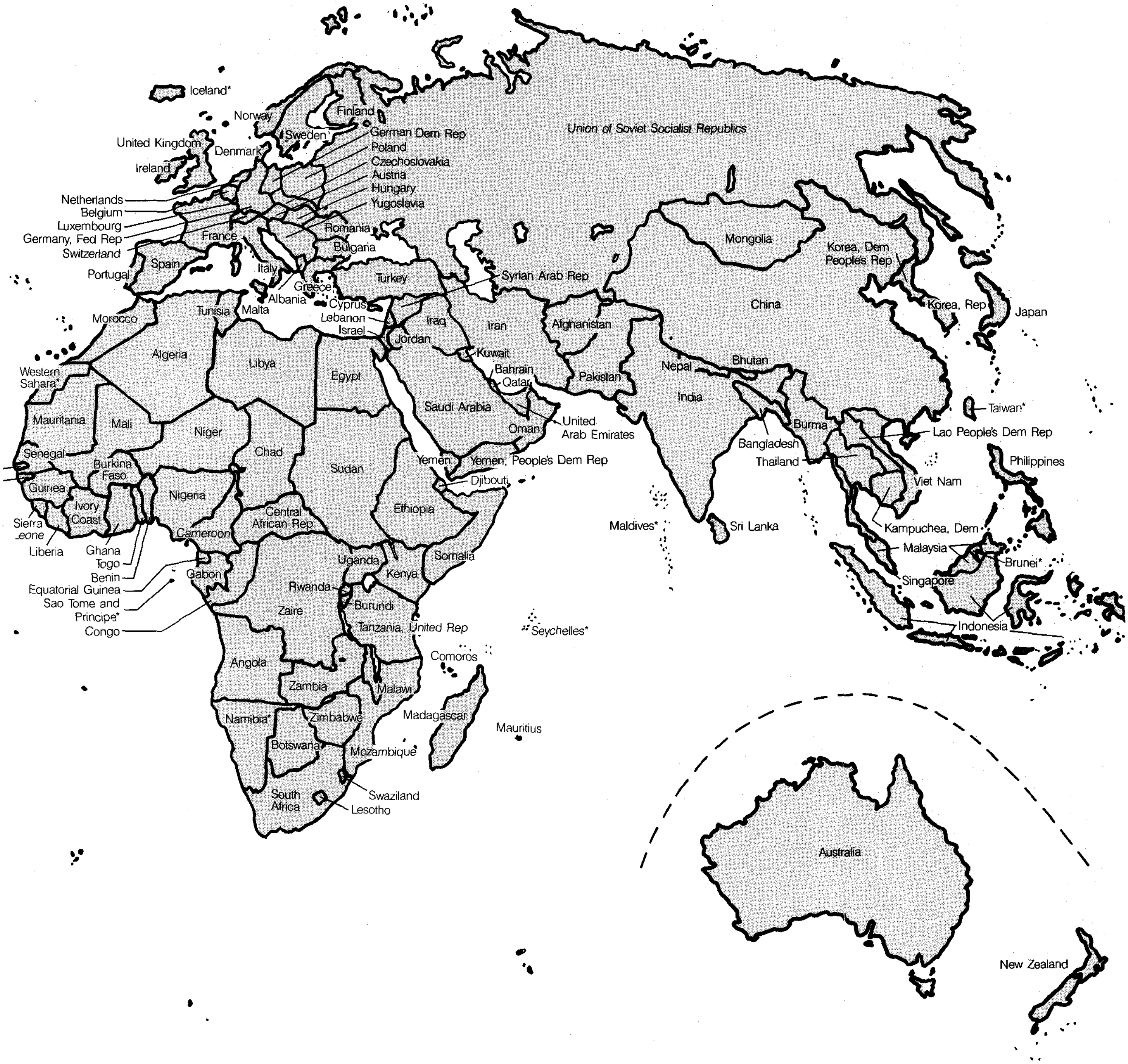
# Appendixes

A: World Map

B: Organizations and Regional Groups

# Appendix A: World Map


*These countries are not included in the data tables in Part IV.


Iceland*
Norway
Finland
Sweden
United Kingdom
Denmark
Ireland
German Dem Rep
Poland
Czechoslovakia
Austria
Hungary
Yugoslavia
Netherlands
Belgium
Luxembourg
Germany, Fed Rep
Switzerland
France
Romania
Bulgaria
Spain
Portugal
Italy
Greece
Albania
Malta
Turkey
Cyprus
Lebanon
Israel
Syrian Arab Rep
Union of Soviet Socialist Republics
Mongolia
Korea, Dem People's Rep
Korea, Rep
Japan
China
Morocco
Tunisia
Algeria
Libya
Egypt
Jordan
Iraq
Iran
Afghanistan
Kuwait
Bahrain
Qatar
Pakistan
Nepal
Bhutan
India
Western Sahara*
Mauritania
Mali
Niger
Chad
Sudan
Saudi Arabia
United Arab Emirates
Oman
Yemen
Yemen, People's Dem Rep
Djibouti
Senegal
Burkina Faso
Guinea
Nigeria
Ivory Coast
Sierra Leone
Liberia
Ghana
Togo
Benin
Equatorial Guinea
Sao Tome and Principe*
Congo
Cameroon
Central African Rep
Ethiopia
Somalia
Uganda
Kenya
Gabon
Rwanda
Burundi
Zaire
Tanzania, United Rep
Seychelles*
Comoros
Angola
Zambia
Malawi
Namibia*
Zimbabwe
Botswana
Mozambique
Madagascar
Mauritius
South Africa
Swaziland
Lesotho
Maldives*
Sri Lanka
Bangladesh
Burma
Thailand
Taiwan*
Lao People's Dem Rep
Philippines
Viet Nam
Kampuchea, Dem
Malaysia
Brunei*
Singapore
Indonesia
Australia
New Zealand

# Appendix B: Organizations and Regional Groups

## ACPE—Asian Centrally Planned Economies

Burma, Union of
China, People's Republic of
Kampuchea, Democratic
Korea, Democratic People's Republic of
Lao People's Democratic Republic
Mongolia
Viet Nam

## ASEAN—Association of Southeast Asian Nations

Brunei
Indonesia
Malaysia
Philippines
Singapore
Thailand

## CIDIE—Committee of International Development Institutions on the Environment

*A non-United Nations organization that examines the environmental aspects of economic development activities.*

African Development Bank
Arab Bank for Economic Development in Africa
Asian Development Bank
Caribbean Development Bank
Commission of the European Communities
European Investment Bank
Inter-American Development Bank
The Organization of American States
The United Nations Development Program
The United Nations Environment Program
The World Bank

## CMEA—Council for Mutual Economic Assistance

Bulgaria
Cuba
Czechoslovakia
German Democratic Republic
Hungary
Mongolia
Poland
Romania
Union of Soviet Socialist Republics
Viet Nam

## DAC—Development Assistance Committee

*A specialized committee of the Organization for Economic Co-operation and Development (OECD).*

Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany, Federal Republic of
Italy
Japan
Netherlands
New Zealand
Norway
Sweden
Switzerland
United Kingdom
United States
Commission of the European Communities

## ECE—Economic Commission for Europe

*A United Nations organization consisting of countries from both Eastern and Western Europe and North America.*

**Eastern Europe**
Bulgaria
Czechoslovakia
German Democratic Republic
Hungary
Poland
Union of Soviet Socialist Republics
  Byelorussian Soviet Socialist Republic
  Ukranian Soviet Socialist Republic

**Western Europe**
Austria
Belgium
Cyprus
Denmark
Finland
France
Germany, Federal Republic of
Greece
Iceland
Ireland
Italy
Luxembourg
Malta
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
Yugoslavia

**North America**
Canada
United States

## EEC—European Economic Community

Belgium
Denmark
France
Germany, Federal Republic of
Greece
Ireland
Italy
Luxembourg
Netherlands
Portugal
Spain
United Kingdom

## IEA— International Energy Agency

*An autonomous body within the Organization for Economic Co-operation and Development (OECD).*

Australia
Austria
Belgium
Canada
Denmark
Germany
Greece
Ireland
Italy
Japan
Luxembourg
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

## IUCN—International Union for Conservation of Nature and Natural Resources

*There are few countries in which the IUCN does not have a member organization. As of August 1984, IUCN's membership included 56 countries, 123 government agencies, 316 national and international non-governmental organizations, and 6 non-voting affiliates.*

## Least Developed Countries

*In 1982, the United Nations General Assembly agreed upon the following three criteria for "least developed countries": a per capita gross domestic product of $285 or less, a share of manufacturing in total gross domestic product of 10 percent or less, and a literacy rate (the proportion of literate persons over 15 years of age) of 20 percent or less. In addition to countries meeting all three of these criteria, borderline cases (in which one criterion was met and the others nearly met) were also included.*

Afghanistan
Bangladesh
Benin
Bhutan
Botswana
Burkina Faso
Burundi
Cape Verde
Central African Republic
Chad
Comoros
Djibouti
Equatorial Guinea
Ethiopia
Gambia
Guinea
Guinea-Bissau
Haiti
Lao People's Democratic Republic
Lesotho
Malawi
Maldives
Mali
Nepal
Niger
Rwanda
Samoa
São Tomé and Principe
Sierra Leone
Somalia
Sudan
Tanzania, United Republic of
Togo
Uganda
Yemen Arab Republic
Yemen, People's Democratic Republic

## OECD—Organization for Economic Co-operation and Development

**North America**
Canada
United States

**Europe**
Austria
Belgium
Denmark
Finland
France
Germany, Federal Republic of
Greece
Iceland
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom
Yugoslavia (special participant)

**Asia**
Australia
Japan
New Zealand
Turkey

## OPEC—Organization of Petroleum Exporting Countries

Algeria
Ecuador
Gabon
Indonesia
Iran
Iraq
Kuwait
Libya
Nigeria
Qatar
Saudi Arabia
United Arab Emirates
Venezuela

## SADCC—Southern African Development Coordination Conference

Angola
Botswana
Lesotho
Malawi
Mozambique
Swaziland
Tanzania, United Republic of
Zambia
Zimbabwe

## SPF—South Pacific Forum

Australia
Cook Islands
Fiji
Kiribati
Nauru
New Zealand
Nive
Papua New Guinea
Solomon Islands
Tonga
Tuvalu
Vanuatu
Western Samoa

## Sub-Saharan Countries

Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Congo
Djibouti
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Ivory Coast
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Niger
Nigeria
Rwanda
São Tomé and Principe
Senegal
Seychelles
Sierra Leone
Somalia
Sudan
Swaziland
Tanzania, United Republic of
Togo
Uganda
Zaire
Zambia
Zimbabwe

# Index

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* Tables
\+ Figures

The World Resources Institute (WRI) is a policy research center created in late 1982 to help governments, international organizations, the private sector, and others address a fundamental question: How can societies meet basic human needs and nurture economic growth without undermining the natural resources and environmental integrity on which life, economic vitality, and international security depend?

The Institute's current program areas include tropical forests, biological diversity, sustainable agriculture, global energy futures, climate change, pollution and health, economic incentives for sustainable development, and resource and environmental information. Within these broad areas, two dominant concerns influence WRI's choice of projects and other activities:

The destructive effects of poor resource management on economic development and the alleviation of poverty in developing countries; and

The new generation of globally important environmental and resource problems that threaten the economic and environmental interests of the United States and other industrial countries and that have not been addressed with authority in their laws.

Independent and nonpartisan, the World Resources Institute approaches the development and analysis of resource policy options objectively, with a strong grounding in the sciences. Its research is aimed at providing accurate information about global resources and population, identifying emerging issues and developing politically and economically workable proposals. WRI's work is carried out by an interdisciplinary staff of scientists and policy experts augmented by a network of formal advisors, collaborators, and affiliated institutions in 30 countries.

WRI is funded by private foundations, United Nations and governmental agencies, corporations, and concerned individuals.

## World Resources Institute

1735 New York Avenue, N.W.
Washington, D.C. 20006 U.S.A.

Founded in 1971, the International Institute for Environment and Development (IIED) is a global organization. Recognizing that productive use of soils, water, forests, and other natural resources was directly linked to economic growth and human needs, IIED was established with Barbara Ward as its President and with sustainable development as its guiding principle.

IIED's sustainable development program includes policy research, information, and field activities. Today, the Institute draws staff from around the world and operates from offices in London, Washington, D.C., and Buenos Aires. Its sustainable development agenda encompasses health and living conditions in the overcrowded cities of the Third World, forestry and land use, renewable energy, fisheries, and sustainable agriculture.

While each of these policy issues has global implications, IIED's approach is attuned toward practical solutions. It utilizes case-by-case analysis and collaboration at the grass roots level, involving national leaders, the private sector, and local people affected by the problem.

The Institute's field activities draw on IIED's policy and information expertise, but are oriented toward Third World organizations and selected governments. These groups share IIED's common pursuit of sustainable development. In 1985, IIED staff and associates worked with non-governmental and private voluntary organizations in 25 countries worldwide, concentrated in Latin America, Africa, and Southeast Asia.

Earthscan, IIED's editorially independent news and communications service, regularly brings timely information on Third World environment and development issues to 3,000 contacts in developing countries, including journalists, private voluntary organizations, and governments.

IIED is funded by private and corporate foundations, international organizations, governments, and concerned individuals.

# IIED

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