DISCUSSION GUIDE FOR
BILL MOYERS REPORTS: EARTH ON EDGE

Ecosystems and the Fraying Web of Life

World Resources Institute
Public Affairs Television, Inc.

World Resources Report
Carol Rosen, Editor-in-Chief
Gregory Mock, Senior Editor
Wendy Vanasselt, Senior Associate/Editor
Janet Overton, Managing Editor
Lori Han, Production Coordinator
Amy Wagener, Research Assistant
Rich Barnett, Outreach and Marketing Director

Reviewers of this Discussion Guide
Peter Adriance, Baha'is of the U.S., Washington, D.C.
Julian Agyeman, Tufts University
Tobin Bechtel, American/International School, Amsterdam
Jennifer Brager, Eastern Technical High School, Baltimore
Robert Miller, consultant
Mary Paden, Academy for Educational Development
Deborah Simmons, Northern Illinois University
Thomas Hudspeth, University of Vermont
Alexandra Miller, student reviewer
Matthew Miller, student reviewer

Funders of this Discussion Guide
The David and Lucile Packard Foundation
The ARIA Foundation
The V. Kann Rasmussen Foundation
Ford Motor Company
World Resources Institute

Funders of the Broadcast
The David and Lucile Packard Foundation
The Park Foundation
The Germeshausen Foundation
The Rockefeller Brothers Fund
The John D. and Catherine T. MacArthur Foundation
The Herb Alpert Foundation
The Surdna Foundation
The Kohlberg Foundation, Inc.
Corporate funding is provided by Mutual of America Life Insurance Company

Bill Moyers Reports: ***Earth on Edge*** is a production of Public Affairs Television, Inc., in collaboration with the World Resources Institute, presented on PBS by Thirteen/WNET in New York.

Producers: Gail Ablow, Leslie Clark, Pamela Hogan
Editors: Alison Amron, Robert Kuhns
Field Producers: Deborah Grau, Candace White
Executive Editor: Bill Moyers
Executive Producers: Judy Doctoroff O'Neill, Judith Davidson Moyers
Director of Production: Felice Firestone
Editorial Consultant: Debbie Rubenstein

About the Documentary *Bill Moyers Reports: Earth on Edge*

In ***Earth on Edge*,** Bill Moyers journeys to five regions of the world where people are working to save their environments. From the Kansas prairie to the hills of South Africa's Cape of Good Hope, from an ancient forest in British Columbia to the grasslands of Mongolia, and into the sea to the coral reefs of Brazil, ***Earth on Edge*** reveals the damaging impact of human activity on the natural environment and the kinds of behavioral changes that can reverse the damage. The individuals profiled in ***Earth on Edge*** are confronting these challenges head on with an understanding that their lives depend on Earth's ecosystems and on their own energy and dedication might help restore these ecosystems.

About this Discussion Guide

This guide introduces readers to the vital importance of ecosystems and how they are threatened. It is based on a study called *World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life*, the most recent edition in the World Resources Report series. The guide can be used along with ***Earth on Edge*** for group discussion or for individual reflection on humanity's impact on the natural environment. Questions included are designed to encourage thought and stimulate conversation. The second section, Taking a Closer Look, revisits the program's story locations and for each of the ecosystems offers a brief summarized version the scientific evidence of the global condition. The third section offers the reader compelling examples of the effects of our impact for further study. The guide will be useful in helping people to understand a variety of ecosystems and also to examine their own.

About the Companion Book *World Resources 2000-2001* and the Pilot Analysis of Global Ecosystems

World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life was prepared by the United Nations Development Programme, the United Nations Environment Programme, the World Bank, and the World Resources Institute, with special financial assistance from the United Nations Foundation. The study features the findings of the Pilot Analysis of Global Ecosystems (PAGE), the first ever global analysis of the five ecosystems humans are most dependent on for health and well-being. Based on the findings of PAGE, a scorecard was developed. In nearly all categories assessed, the report shows failing grades. We are depleting our planet of the water, arable land, biodiversity and clean air we require to survive—and the sea is rising. The book offers an alternative, a new "ecosystem approach" to managing ecosystems that, if adopted, provides for an alternative future. To obtain copies of *World Resources 2000–2001*, visit www.wri.org, call 1-800-822-0504, or write to World Resources Institute Publications, PO Box 4852, Hampden Station, Baltimore MD 21211, or email publications@wri.org. To review the PAGE data, visit www.wri.org/wr2000/page.html.

About the Millennium Ecosystem Assessment

The broadcast of ***Earth on Edge*** coincides with the launch of the Millennium Ecosystem Assessment, an international scientific effort to gauge the health of the world's ecosystems. Preliminary findings, the PAGE results, are featured in *World Resources 2000–2001*. Visit the Millennium Ecosystem Assessment (MA) web site (www.millenniumassessment.org) to learn more.

About the Companion Web Site

The ***Earth on Edge*** web site (www.pbs.org/earthonedge) features more information about ecosystems and was developed for use in communities in the US and around the world. The information provided can help people assess the condition of the ecosystems in which they live, understand the impact their activities have on their environment, and develop ways to monitor environmental change, reduce the detrimental effects of their activities, and build on their new-found knowledge to improve their environments.

Videotaping Rights

Earth on Edge is available on video from Films for the Humanities and Sciences. Copies for educational use include public performance rights for $149.00. Home videos are available for private use at a price of $29.95. For further information, or to place an order, call 1-800-257-5126, or visit the web site at www.films.com.

Off-air taping rights are available to high school educators for one year following each broadcast release.

Dear Reader,

It seems that almost every day the news reports another distress signal from Earth. The human imprint that you and I and the other six billion of us are leaving on the natural world is taking a relentless toll on the life-support systems—the ecosystems—that sustain us. Yet we know too little about what is happening to each ecosystem and what we must do to arrest and reverse the damage.

Fortunately, scientists around the globe are now collaborating on gathering the data that we need to assess the challenge and take action. In 1999, some of the world's leading environmental organizations initiated the Pilot Analysis of Global Ecosystems, an unprecedented analysis of the world's rivers and reefs, forests and wetlands, agricultural land and grazing ground. This research began to explore the condition of the major ecosystems, the causes of their deterioration, and their continuing capacity to support us.

This remarkable report was the genesis for our PBS report, *Earth on Edge*, which premiered in June 2001 in conjunction with the launch of the Millennium Ecosystem Assessment, the next step in the international effort to measure the health of our world's ecosystems. In *Earth on Edge* we took a close look at five ecosystems from the Kansas prairie to the hills of South Africa's Cape of Good Hope, from an ancient forest in British Columbia to the grasslands of Mongolia, and down below the sea to the coral reefs of Brazil. These reports described the impact of human activity on each environment and suggested the kind of behavioral changes that can restore it. As the reporting made clear, the time for change is running out, as ecosystems approach critical environmental thresholds that may be irreversible. But there is still time, and reason for hope. On its journey around the globe, *Earth on Edge* profiled prophetic and courageous individuals who are confronting our environmental problems head on, people who understand how their lives depend on Earth's ecosystems and how their own energy and dedication might help restore them. In this discussion guide, I hope you will find the seeds for actions that you can take at home, in the classroom, and at work. Like the scientists in *Earth on Edge*, we too have an individual responsibility to do what we can to preserve the Earth's ecosystems.

Last Thanksgiving my eight-year-old grandson asked me "How old are you, Pa?" When I told him 66, he said, "What will the world look like when I'm as old as you?" A child's question brought me face to face with the necessity of trying to imagine the future concretely. The work of the Millennium Ecosystem Assessment is crucial to understanding what must be done in our generation to assure a fair and decent world for generations to come.

Bill Moyers

Contents

SECTION I:
TALKING ABOUT ECOSYSTEMS

HOW TO USE THIS GUIDE

This guide can be adapted and used in colleges and secondary schools, as well as in community discussion groups. We suggest that before beginning, you review the guide. Consider the discussion questions following the different sections and the "Rethinking the Link" questions. You may want to select one or two ecosystems for your discussion. If so, review Section 2 and the "Exploring Your Links" questions.

If you have a cassette of the program, you should preview it.

Before Watching the Program

READ THE FOLLOWING ALOUD OR JOT SOME POINTS DOWN:
"Ecosystems are communities of interacting organisms and the physical environment in which they live. Ecosystems provide us with everything we need to exist on this planet—from the water we drink to the food we eat and from the fiber we use for clothing, paper, and lumber to the peace we gain when we enjoy the beauty of nature.

All organisms have intrinsic value: grasslands, forests, rivers, and other ecosystems do not exist to serve humans alone. But the discussion is deliberately geared toward examining management of ecosystems for what they provide for humans because humans are the primary source of pressure on ecosystems. Nearly every measure we use to assess the health of ecosystems tells us we are drawing on them more than ever and degrading them at an accelerating pace."

DISCUSS THE FOLLOWING:
What kind of ecosystems do you live in? Work in? Vacation in?
Agricultural? Forest? Freshwater? Grassland? Coastal? Urban?

What does your local ecosystem provide that you use or benefit from? Which of those ecosystem goods and services are most valuable to you? Why?
For a list of goods and services provided by each ecosystem, see the chart on page 3.

Think about the questions listed below as you watch ***Earth on Edge***. They will help you explore your knowledge of and perceptions about ecosystems. You can use them as a framework for discussion with friends and family or to provoke your own thinking during the program.

- What are the greatest pressures that people have placed on the ecosystems in your community? Pollution? Conversion? How have these pressures changed since the 1950s?
- How have you seen these changing pressures affect your ecosystem's health in the past five or ten years? In the past thirty or fifty years? (Talk to an older friend or family member if you're too young or new to the community to answer this question.)
- What changing human demands and pressures do you foresee in the coming decade? How do you think your local ecosystem will be affected by those changes? Who would benefit most and who would pay the costs of those changes?

WHAT ARE ECOSYSTEMS?

Ecosystems are communities of interacting organisms and the physical environment in which they live. Ecosystems are the woodlands where we live, hunt, cut timber, or hike; the lakes, streams, and rivers we fish, boat, transport our goods on, and tap for water; the rangelands where we graze our cattle; the farmlands we till; the beaches where we play, and the marine waters we trawl; the urban parks and green spaces we stroll and even the buildings and roads of these same cities. In effect, every centimeter of the planet is part of an ecosystem.

"Ecosystem" can refer to a small bog, a single sand dune, or a tiny patch of forest. But ecosystems are also forests or a major river system, each with many microenvironments. Ecosystems can be both "natural," such as forests or rangeland tracts that retain much of their original structure and "managed," such as farms, pastures, or forest plantations. Both "managed" and "natural" ecosystems are living systems capable of producing an array of benefits, and both are crucial to human survival.

This guide focuses on five main categories of ecosystems: agricultural, freshwater, grassland, forest, and coastal ecosystems. Together these five ecosystems cover most of the Earth's surface and render the bulk of the goods and services people derive from ecosystems. In addition, this guide profiles the urban ecosystem—a key source of demands on other ecosystems.

Because all ecosystems are affected by changes and pressures on the others, jurisdictional divisions between ecosystems are less important than the physical and systemic linkages between them. Grasslands give way to savannas that segue into forests. Freshwater becomes brackish as it approaches a coastal area. Polar, island, mountain, even urban ecosystems—all these systems are tightly knit into a global web of energy, nutrients, and organisms. Typically, we don't recognize ecosystems as cohesive units because they often extend across political and management boundaries, which segment them artificially. In looking at them in pieces or concentrating on the specific products they yield, we miss their complexity, the interdependence of their organisms—the very qualities that make them productive and stable.

> "You may feel this sense that, "Why should you care?" you know? But no man is an island, no ecosystem is an island. Everything's interconnected, and there is a meaning for all of this. Everything depends on everything. So you might feel the effects much later when it's too late. That's why you should care to begin with."
> *—Beatrice Ferreira, marine biologist, Brazil*

Why Care about Ecosystems?

Ecosystems sustain us. They are Earth's primary producers—solar-powered factories that yield the food, fiber, and water that sustain us at an efficiency level unmatched by human technology. Ecosystems also provide essential services like air and water purification, climate control, nutrient cycling, and soil production.

Harvesting the bounty of ecosystems roots our economies and provides employment, particularly in low- and middle-income countries. Agriculture, forestry, and fishing are responsible for 50% of all jobs worldwide and 70% of the jobs in sub-Saharan Africa, East Asia, and the Pacific. In 25% of the world's nations, crops, timber, and fish still contribute more to the economy than industrial goods. Global agriculture alone produces $1.3 trillion in food and fiber each year.

In every respect, our lives are closely linked to the productivity of ecosystems. Our future rests squarely on their continued viability.

Losing Our Link

For the millions of us who depend directly on forests or fisheries for our survival, the importance of ecosystems is a fact of life. But for the millions of us, who live in cities or suburbs and have transitioned from working the soil to working at computer keyboards, our link to ecosystems is less obvious. To many who live in cities, large and small, the places profiled in ***Earth on Edge***, even the farms of the Midwest, may sound far away and unfamiliar.

It is easy to lose touch with our link to ecosystems, despite their importance. Many of us buy our food and clothing in stores and depend on technology to deliver water and energy. We take for granted that there will be food in the market, that transportation and housing will be available, and all at reasonable costs. Too often, we're only reminded of our link to natural systems when a fishery collapses, a reservoir goes dry, or air pollution makes us sick—when the flow of goods and services is disrupted. Then we suddenly become aware of the real value of these resources and the potential economic and biological costs of mismanagement.

Though it may be easy to lose a sense of connection to ecosystems, in reality every day our choices and actions affect ecosystems in some way.

> **BILL MOYERS:** You know, I live in the heart of Manhattan. Why should I care about how you farm out here, as long as I get the food I need?
>
> **CHARLIE MELANDER:** Because the equation's not that simple. The food you get is produced in a complicated process. And one of the costs can be polluted water. And even in New York, you're going to need good water. You're also going to need fields back in Kansas that haven't eroded for future generations. So, whether you like it or not. You're going to be affected by what we do or don't do.

Questions to consider:

1 What ecosystems can you list that exist in and around your community? In what ways do you interact with these and other ecosystems?
2 Think about the most recent meal you ate. Did you buy it all in a supermarket? Did the labels tell you where the food came from? Did you pay attention to the list of ingredients? Do you buy food at a local farmers' market?
3 The clothes you're wearing, were they manufactured in the US? Does the label say where the material came from?
4 Describe how each ecosystem contributes to a) your employment, b) your living circumstances, and c) your sense of well-being.

What Is the State of Ecosystems Today?

Goods and Services

Food Production: We have dramatically increased food production, in part by converting large areas to croplands, pastures, and feedlots. Although crop yields are still increasing, the underlying condition of agroecosystems is declining in much of the world. Historically, inputs of water, pesticides, fertilizers, and technologies such as new seed varieties have been able to offset declining ecosystem conditions worldwide (although with significant local and regional exceptions), and they may continue to do so for the foreseeable future. But at what cost to the health and continuing productivity of the ecosystem?

Primary Goods and Services Provided by Ecosystems

Ecosystem	Goods	Services
Agroecosystems	• Food crops • Fiber crops • Crop genetic resources	• Maintain limited watershed functions (infiltration, flow control, partial soil protection) • Provide habitat for birds, pollinators, soil organisms important to agriculture • Build soil organic matter • Sequester atmospheric carbon • Provide employment
Coastal Ecosystems	• Fish and shellfish • Fishmeal (animal feed) • Seaweeds (for food and industrial use) • Salt • Gentic resources	• Moderate storm impacts (mangroves; barrier islands) • Provide wildlife (marine and terrestial) habitat • Maintain biodiversity • Dilute and treat wastes • Provide harbors and transportation routes • Provide human habitat • Provide employment • Provide for aesthetic enjoyment and recreation
Forest Ecosystems	• Timber • Fuelwood • Drinking and irrigation water • Fodder • Nontimber products (vines, bamboos, leaves, etc.) • Food (honey, mushrooms, fruit, and other edible plants; game) • Genetic resources	• Remove air pollutants, emit oxygen • Cycle nutrients • Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) • Maintain biodiversity • Sequester atmospheric carbon • Moderate weather extremes and impacts • Generate soil • Provide employment • Provide human and wildlife habitat • Provide for aesthetic enjoyment and recreation
Freshwater Systems	• Drinking and irrigation water • Fish • Hydroelectricity • Genetic resources	• Buffer water flow (control timing and volume) • Dilute and carry away wastes • Cycle nutrients • Maintain biodiversity • Provide aquatic habitat • Provide transportation corridor • Provide employment • Provide for aesthetic enjoyment and recreation
Grassland Ecosystems	• Livestock (food, game, hides, fiber) • Drinking and irrigation water • Genetic resources	• Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) • Cycle nutrients • Remove air pollutants, emit oxygen • Maintain biodiversity • Generate soil • Sequester atmospheric carbon • Provide human and wildlife habitat • Provide employment • Provide for aesthetic enjoyment and recreation

> *Fully 65% of cropland worldwide has experienced some degree of soil degradation.*

The outlook for fish production—also a major source of food—is more problematic. The condition of coastal ecosystems for food production is only fair and becoming worse. Twenty-five percent of the world's most important marine fish stocks are depleted, overharvested, or just beginning to recover from overharvesting. Another 44% are being fished at their biological limit and are, therefore, vulnerable to depletion. Freshwater fisheries present a mixed picture; introduced species have begun to enhance harvests in some areas but often pose a risk to the native species. Overall, the pattern of growing dependence on aquaculture and the decline of natural fish stocks will have serious consequences for many of the world's poor who depend on subsistence fishing. (See "Trade-Offs: Lake Victoria's Ecosystem Balance Sheet" on page 23.)

> *Roughly 70% of the major marine fish stocks are either deplete from overfishing or are being fished at their biological limit.*

Water Quantity: Dams, canals, and other diversions; pumps and other engineering works have profoundly altered the amount and location of water available for both human use and for sustaining aquatic ecosystems. Dams have so impeded flows that the length of time it takes the average drop of water entering a river to reach the sea has tripled. The changes we have made to forest cover and wetlands also have altered water availability and affected the timing and intensity of floods. Freshwater wetlands, which store water and moderate flooding, have been reduced by as much as 50% worldwide.

Water Quality: We have greatly exceeded the capacity of many freshwater and coastal ecosystems to maintain healthy water quality. Water quality is degraded directly through chemical or nutrient pollution, or indirectly when the capacity of ecosystems to filter water is degraded or when land-use changes increase soil erosion. Nutrient pollution from fertilizer-laden runoff is a serious problem in agricultural regions around the world. Although developed countries have improved water quality to some extent; water quality in developing countries—particularly near urban and industrial areas—has degraded substantially. Declining water quality poses a particular threat to the poor who often lack ready access to potable water and are most subject to the diseases associated with polluted water.

> "While human population has doubled since 1940, human water consumption has quadrupled. Now what's that about? Well, quite simply, we use that water to produce the food that feeds all of those extra people. So water extraction for irrigation and for agriculture is really, at the moment, the greatest user of the world's water. To basically grow the crops to feed our population."
> *—Melanie Stiassny, American Museum of Natural History*

Carbon Storage: Plants and soil organisms remove carbon dioxide (CO_2)—the most abundant greenhouse gas—from the atmosphere and store it in their tissues, helping to slow the buildup of CO_2 in the atmosphere. Unfortunately, as we alter the landscape to increase production of food and other commodities, we reduce the capacity of the landscape to store carbon. This is particularly true as we convert forests to agricultural lands because forests are the primary land-based carbon storage systems (oceans store more carbon). Conversion is in fact an important source of carbon emissions, contributing more than 20% of global annual carbon emissions. How we manage these ecosystems—whether we promote afforestation and other carbon-storing strategies or continue to convert forests to agriculture or urban uses—will significantly impact levels of atmospheric carbon dioxide.

Besides affecting the carbon cycle, human activities are significantly altering all the basic chemical cycles that ecosystems depend on. This strikes at the foundation of ecosystem functioning and adds to the fundamental stresses that ecosystems face at a global scale. (See "Are We Altering Earth's Basic Chemical Cycles?" on page 24.)

> "I think that people don't realize that a whole lot more species of plants are threatened with extinction or have become extinct than animals. And I think we tend to forget sometimes, as human beings, how dependent we are on plants. We are dependent on plants for food, we are dependent on plants for cleaning the air, we are dependent on plants for storing carbon, we are dependent on plants for producing medicine, we are dependent on plants for aesthetic reasons, for religious reasons, for cultural reasons. Basically, without plants we won't survive."
> *—Brian Van Wilgen, ecologist, South Africa*

Biodiversity: Biodiversity—the diversity of species in an ecosystem—undergirds the sustainability of an ecosystem. Biodiversity provides genetic material for crop and livestock breeding, chemicals for new medicines, aesthetic beauty, and is a source of wonder. Reducing the biological diversity of an

> "The concept of ecosystems is an empowering reminder that the sum impact of our daily activities and choices as individuals are inextricably linked to the complexity of local, regional and global environmental systems."
> *—Katherine Foster , Multilateral Environment Officer Canadian Embassy, Ambassade Du Canada, Washington, D.C.*

ecosystem can diminish its resilience to disturbance, increase its susceptibility to disease outbreaks, and decrease its productivity.

The erosion of global biodiversity over the past century is alarming. Major losses have occurred in virtually all types of ecosystems, much of it by simple loss of habitat. It is estimated that forest cover has been reduced by as much as 50% worldwide; 50% of wetlands and more than 90% of grasslands have also been lost.

Pollution, overexploitation, competition from invasive species, and habitat degradation also threaten many species. Freshwater biodiversity is far and away the most degraded, with some 20% of freshwater fish species extinct, threatened, or endangered in recent decades. Forest, grassland, and coastal species all face major problems as well. The rapid increase in the incidence of diseases affecting marine organisms, the increased prevalence of algal blooms, and significant declines in amphibian populations all attest to the severity of the threat to global biodiversity.

Recreation and Tourism: The health of ecosystems is declining in many areas because of the overall degradation of biodiversity as well as the direct impacts of urbanization, industrialization, and tourism itself. It is likely that the pressures from these demands will continue to grow significantly.

> *Destructive fishing practices, tourist pressures, and pollution potentially threaten some 58% of coral reefs.*

Increasing Demands, Increasing Pressures

Behind all the pressures impinging on ecosystems are two basic drivers: human population growth and increasing consumption. Since 1980, the global economy has tripled and the population has grown 30% to 6 billion people. Consumption of everything from rice to paper to refrigerators to oil has risen in tandem—all at a cost to ecosystems. And these pressures are not likely to abate soon. Economists predict the global economy may expand by a factor of five in the next 50 years. Demographers expect the population to grow to 9 billion in the same period. Demand for rice, wheat, and maize is expected to grow 40% by 2020, pushing water demand for irrigation up 50% or more. By 2050, demand for wood could double.

Declines in the productive capacity of ecosystems can have devastating human costs. Too often, the poor are the first and most directly affected by the degradation of ecosystems. Impoverished people are generally the most dependent on ecosystems for subsistence and cash, but usually exert the least control over how their local ecosystems are used or who reaps the benefits of that use. In many areas, declining agricultural productivity, diminished supplies of freshwater, reduced timber yields, and declining fish harvests have already taken a significant toll on local economies.

- In Canada's maritime provinces, collapse of the cod fishery in the early 1990s from overfishing left 30,000 fishers dependent on government welfare payments and decimated the economies of 700 communities in Newfoundland alone.
- Residents of more than 100 of China's major cities face severe water shortages in part because of overextraction and pollution of nearby rivers and groundwater sources.
- Commercial cutting of India's forests has almost destroyed the traditional village system of managing the forests and has led to shortages of fuel and building materials for millions of rural villagers.

Others of us may not feel the costs so dramatically, but as the productivity of an ecosystem declines we will all eventually feel the effect. If we choose to continue our current patterns of use, we face almost certain declines in the ability of ecosystems to yield their broad spectrum of benefits—from clean water to stable climate, fuelwood to food crops, and timber to wildlife habitat. A series of small changes, each seemingly harmless, can result in cumulative impacts that are irreversible; this is called the "tyranny of small decisions."

> "You know in the past we've tried to save a panda, or a tiger, whatever. And you know we now realize that we have to save the whole ecosystem, not just the particular thing of interest, but everything that it's connected to – including the people that live in that ecosystem. They're part of it."
> *—Adrian Forsyth, biologist, Amazon Conservation Association*

"I maintain that we could change our environment almost overnight, if suddenly we said we'll reward less fuel usage, less herbicide usage, less fertilizer usage... Originally I was really pessimistic, but now, from what I'm doing I can see that there are some simple things we can do to really make a difference, that wouldn't have to cost a penny more than what we're spending."
—Charlie Melander, farmer, Kansas

Economic and Political Factors

These basic ecosystem pressures are exacerbated by economic and political factors that influence how and what we consume and where it comes from. Too often, these factors encourage us to exploit ecosystems for short-term gain and discourage long-term stewardship. The prices we pay for food, water, or the hundreds of other ecosystem goods we purchase typically don't reflect the real cost to the environment of harvesting them. So we undervalue them and use more than we need.

Government subsidies for commodities such as water, pesticides, and fishing boats can contribute to the damage. Worldwide, governments spend about US$700 billion a year subsidizing environmentally unsound practices in the use of water, agriculture, energy, and transport. Other societal factors—lack of land tenure, armed conflict, and government corruption—add to the pressure to overexploit ecosystems. (See "Domesticating the World: Conversion of Natural Ecosystems" on page 25.)

Questions to consider:

1 What problems have you seen in the ecosystems in your community?
2 What are the biggest pressures on those ecosystems?
3 Do government subsidies or policies affect the goods and services provided by your ecosystem?
4 Can you envision a different "reward" system that would encourage sustainable practices?

Trade-Offs

The decision to mange or alter an ecosystem involves trade-offs. Not all benefits can be obtained at the same time, and maximizing one benefit may reduce or eliminate others. For example, a tree plantation may efficiently produce timber or pulp, but compared with a natural forest it is lacking in biodiversity, habitat value, and scenic beauty. Likewise, damming a river may increase the water available for irrigation or hydroelectric power production and decrease the danger of floods, but it may also disrupt natural breeding cycles of fish and damage aquatic habitats downstream by diverting water or releasing it at inappropriate times.

Human management of ecosystems often involves trade-offs—increasing one good or service at the expense of others. Every management decision becomes either an opportunity for enlightened management or an occasion for degradation. It is difficult to consider the consequences on ecosystems when we decide to use natural resources for many reasons.

- Economic growth is the driving force behind governments and businesses; assessing trade-offs will require them to rethink some basic assumptions affecting development decisions.
- Poverty forces many people to overuse the ecosystems on which they depend, even when they know that they are cutting timber or extracting fish at unsustainable levels.
- Greed, enterprise, ignorance, and inattention also lead people to disregard the natural limits that sustain ecosystems.

Considering the consequences may also be clouded by the fact that ecosystems can be in good condition for producing some goods or services, but in poor condition for producing others. For example, a tree plantation may efficiently produce timber or pulp, but is generally impoverished in terms of biodiversity, habitat value, and scenic beauty compared with a natural forest. Judging the overall condition of the ecosystem means assessing the capacity of the ecosystems over time to provide each of the various goods and services, and then evaluating the trade-offs among them.

To a certain extent, we accept these trade-off as necessary to efficiently produce food, power, and other things we need. Historically, we have been hugely successful at selectively increasing those ecosystems goods we value most. It is only recently that we have begun to focus on the dangers of such trade-offs.

Questions to consider:

1 Which goods and services would you be willing to give up to get more of another?
2 Would your point of view be different if you worked for a government agency? An environmental non-profit organization? If you lived in a neighboring city or town?
3 What if you had more money? Less money?

Primary Human-Induced Pressures on Ecosystems

Ecosystem	Pressures	Causes
Agroecosystems	• Conversion of farmland to urban and industrial uses • Water pollution from nutrient runoff and siltation • Water scarcity from irrigation • Degradation of soil from erosion, shifting cutlivation, or nutrient depletion • Changing weather patterns	• Population Growth • Increasing demand for food and industrial goods • Urbanization • Government policies subsidizing agricultural inputs (water, research, transport) and irrigation • Poverty and insecure tenure • Climate change
Coastal Ecosystems	• Overexploitation of fisheries • Conversion of wetlands and coastal habitats • Water pollution from agricultural and industrial sources • Fragmentation or destruction of natural tidal barriers or reefs • Invasion of nonnative species • Potential sea level rise	• Population growth • Increasing demand for food and coastal tourism • Urbanization and recreational development, which is highest in coastal areas • Government fishing subsidies • Inadequate information about ecosystem conditions, especially for fisheries • Poverty and insecure tenure • Uncoordinated coastal land-use policies • Climate change
Forest Ecosystems	• Conversion or fragmentation resulting from agricultural or urban uses • Deforestation resulting in loss of biodiversity, release of stored carbon, air and water pollution • Acid rain from industrial pollution • Invasion of nonnative species • Overextraction of water for agricultural, urban, and industrial uses	• Population growth • Increasing demand for timber, pulp, and other fiber • Government subsidies for timber extraction and logging roads • Inadequate valuation of costs of industrial air pollution • Poverty and insecure tenure
Freshwater Systems	• Overextraction of water for agricultural, urban, and industrial uses • Overexploitation of inland fisheries • Building dams for irrigation, hydropower, and flood control • Water pollution from agricultural, urban, and industrial uses • Invasion of nonnative species	• Population growth • Widespread water scarcity and naturally uneven distribution of water resources • Government subsidies of water use • Inadequate valuation of costs of water pollution • Poverty and insecure tenure • Growing demand for hydropower
Grassland Ecosystems	• Conversion or fragmentation owing to agricultural or urban uses • Induced grassland fires resulting in loss of biodiversity, release of stored carbon, and air pollution • Soil degradation and water pollution from livestock herds • Overexploitation of game animals	• Population growth • Increasing demand for agricultural products, especially meat • Inadequate information about ecosystem conditions • Poverty and insecure tenure • Accessibility and ease of conversion of grasslands

THE PILOT ANALYSIS OF GLOBAL ECOSYSTEMS

The biggest difficulty of all is that people at all levels, from the farmer to the policy maker in the capital, either lack the basic information about the condition and long-term prospects of ecosystems or can't make good use of the knowledge at hand. While our knowledge of ecosystems has increased dramatically, it has simply not kept pace with our ability to alter them.

One way to judge the condition or state of ecosystems is to evaluate their ability to produce the goods and services we rely on. This is the approach taken by the Pilot Analysis of Global Ecosystems (PAGE), which compares information already available on a global scale about the condition of agroecosystems, coastal areas, forests, freshwater systems, and grasslands. PAGE examines not only the quantity and quality of outputs but also the biological basis for production, including soil and water condition, biodiversity, and changes in land use over time.

And rather than looking at only marketed products, such as food and timber, PAGE also evaluates the condition of a broad array of ecosystem services that people rely on but don't buy in the marketplace, like water filtration, pollination, biodiversity, and carbon storage to name just a few. The bottom line is a comprehensive evaluation, based on available information, of the current condition and capacity of five major ecosystems. For each of a select list of goods and services, PAGE asked:

- What is the quantity of the good or service being produced?
- Is the capacity of the ecosystem to produce it being enhanced or diminished through time?

PAGE Findings: The Ecosystem Scorecard

The PAGE findings are represented as two separate "scores" for each ecosystem's primary goods and services. The "Condition" score reflects how the ecosystem's ability to yield goods and services has changed over the last 20-30 years. The score is based on a variety of data for each ecosystem—from data on food production, wood production, water use, and tourism to data on biological conditions, such as species declines, biological invasions, or the amount of carbon stored in the vegetation and soils of a given ecosystem.

The "Changing Capacity" score reflects an ecosystem's ability to continue to provide a good or service in the future. For the different ecosystems, scores integrate information on factors such as soil fertility, erosion, and salinization; condition of fish stocks and breeding grounds; nutrient loading and eutrophication of water bodies; fragmentation of forests, freshwater systems, and grasslands; and disruption of local and regional water cycles.

The PAGE evaluation also shows the strengths and weaknesses of the information at hand. The analysis identifies significant gaps in the data and what it would take to fill those gaps. Satellite imaging and remote sensing, for example, have added to information about certain features of ecosystems, such as their extent, but on-the-ground information for such indicators as freshwater quality and river discharge is less available today than in the past. In addition, though some data are being created in abundance, the pilot analysis shows that we have not yet succeeded in coordinating our efforts. Scales now diverge, differing measures defy integration, and different information sources may not know of each other's relevant findings.

Although far from perfect, the Condition and Changing Capacity scores, when taken together, offer a picture of how ecosystems are serving us today and their trends for the future. (The PAGE scorecards for each of the five major ecosystems are in Section 2.)

The Bottom Line

There are numerous signs of ecosystems' decreasing capacity to continue to produce adequate amounts of the goods and services we depend on. In all five ecosystems, PAGE confirms that major pressures on ecosystems—overuse, conversion, pollution, fragmentation, and biological invasions—continue to grow in scale and pervasiveness. Though these factors lead to degraded ecosystems, there's been no general, global decrease in the availability or production of goods and services. Worldwide, food and fiber production have never been higher, and dams allow unprecedented control of water supplies. But this wealth of production is, in many instances, due to intensive management that threatens future production as well as ecosystems. Our use of technology—whether it is artificial fertilizer, more efficient fishing gear, or water-saving drip-irrigation systems—by keeping production levels of food and fiber high, masks the actual overall decrease in biological capacity of these systems. However, technology cannot as easily mask the reduction in biodiversity, water quality, and carbon storage. The PAGE findings starkly illustrate the trade-offs between high commodity production and impaired ecosystem services, and indicate the dangers these choices pose to the long-term productivity of ecosystems.

How Can We Best Manage Ecosystems?

In some areas, we have made progress in our understanding of ecosystems and how to treat them. People in all parts of the world are working to find solutions: community forest conservation programs in Dhani, India; collective management of grasslands in Mongolia; agricultural transformation from Kansas to Machakos, Kenya; removal of invasive tree species to protect water resources in South Africa; and restoration of the Florida Everglades. Governments and private interests are spending billions trying to rectify ecosystem degradation or, at least, stave off the conse-

> ". . . this is our knowledge base, this is what we are putting forward to you. Argue with us, discuss it with us, but at least try to move forward in making sure that the Earth doesn't collapse as a system that can support human life and human beings."
> *—Habiba Gitay, Australian National University*

quences—and countless billions more may be needed to restore ecosystems on a global scale.

Yet these are only isolated instances. They fall short of the broad-scale change in thinking that must take place if we are to cope with current environmental degradation and projected increases in consumption. Shortsighted, avoidable mistakes can affect the lives of millions of people, now and in the future. We can continue blindly altering Earth's ecosystems, or we can learn to use them more sustainably.

What is required today is a worldwide adoption of an ***ecosystem approach*** to environmental management. It requires reorienting how we see ecosystems, so that we learn to view their sustainability as essential to our own. Adopting this "ecosystem approach" means we evaluate our decisions on land and resource use in terms of how they affect the capacity of ecosystems to sustain life, not only human well-being but also the health and productive potential of plants, animals, and natural systems. Maintaining this capacity becomes our passkey to human and national development, our hope to end poverty, our safeguard for biodiversity, our passage to a sustainable future.

Questions to consider:

1. Which ecosystems in your community should be preserved? Do you think any of them are expendable? Why or why not?
2. What steps could be taken to preserve ecosystems that are endangered? In your community? In threatened areas around the world?

WHAT IS AN ECOSYSTEM APPROACH?

It's hard, of course, to know what will be truly sustainable in either the physical or political environments of the future. That's why the ecosystem approach emphasizes the need for both good scientific information and sound policies and institutions.

An ecosystem approach is an integrated approach. Currently, we tend to manage ecosystems for one dominant good or service such as fish, timber, or hydropower without fully realizing the trade-offs we are making. In doing so, we may be sacrificing more valuable goods or services, such as biodiversity and flood control, which are not yet valued in the marketplace. An ecosystem approach considers the entire range of possible goods and services and attempts to optimize the benefits for a given ecosystem and across ecosystems. Its purpose is to make trade-offs efficient, transparent, and sustainable.

An ecosystem approach reorients the boundaries that traditionally have defined our management of ecosystems. It emphasizes a systemic approach, recognizing that ecosystems function as whole entities and need to be managed as such, not in pieces. Since ecosystems often cross state and national lines, this approach looks beyond traditional jurisdictional boundaries.

An ecosystem approach takes the long view. It respects ecosystem processes at the micro level, but also sees them in the larger frame of landscapes and decades, working across a variety of scales and time dimensions.

An ecosystem approach includes people. It integrates social, economic, and environmental information about the ecosystem. It thus explicitly links human needs to the biological capacity of ecosystems to fulfill those needs. Although it is attentive to ecosystem processes and biological thresholds, it acknowledges an appropriate place for human modification of ecosystems.

An ecosystem approach maintains the productive potential of ecosystems. An ecosystem approach is not focused on production alone. It views production of goods and services as the natural product of a healthy ecosystem, not as an end in itself. Within this approach, management is not successful unless it preserves or increases the capacity of an ecosystem.

Adopting an Ecosystem Approach

Adopting an ecosystem approach requires viewing our activities through the living lens of ecosystems. That lens is the only clear view we have of our future. Consider the steps below and the questions that follow in creating an ecosystem approach in your community.

Tackle the "information gap." Managing ecosystems effectively requires knowing how they function and what their current condition is. Having detailed knowledge of ecosystems enables us to see the trade-offs we are making as we manage them, and to assess the long-term consequences of these trade-offs.

Set an explicit value on ecosystem services. Undervaluing ecosystem services has been one of the primary factors behind many of the short-sighted management practices of the past. One essential element of an ecosystem approach is helping communities, governments, and industries assign more accurate values to ecosystem services, so that they can factor these values into their planning processes.

Engage a public dialog on trade-offs and management policies. Under an ecosystem approach, the goals for ecosystem management are derived through an informed public discussion of what we want and need from ecosystems, how the benefits should be distributed, and what we can tolerate in costs and trade-offs.

Involve local communities in managing ecosystems. Examples from across the globe make it clear that local communities are often the most prudent ecosystem managers. Their knowledge of the ecosystem and their direct stake in its health can improve the chances for long-term stewardship. Involving local communities in ecosystem management can also yield a more equitable distribution of the benefits and costs of ecosystem use.

Evaluate the potential for ecosystem restoration. In the last 20 years the scientific basis for restoration has greatly improved, and interest in and spending on restoration has surged. However, we do not have a good estimate of the total degradation of ecosystems globally or an idea of how much of this degradation can be addressed through restoration efforts.

Integrate urban planning into ecosystem management. Urbanization and urban consumers are among the most significant pressures on ecosystems today. Properly managed, urban areas can reduce these pressures through economies of scale in housing, transportation, and energy use. Ignoring cities or considering them peripheral to prudent ecosystem management is counterproductive.

Pursue new approaches to parks and protected areas. An ecosystem approach will require new arrangements that integrate human activities with conservation goals. Parks and protected areas must fit within an overall strategy of landscape management that takes into consideration human activities. In some instances, it may be necessary to physically link landscape corridors so that the ecosystem can continue to function.

RETHINKING THE LINK: QUESTIONS TO CONSIDER AFTER VIEWING THE VIDEO

Taking an Ecosystem Approach

- What are your community's goals for ecosystem management? What would it mean for your home community to take an "ecosystem approach" to natural resource management? What changes would need to occur? How might these changes affect your daily life?
- What kinds of indicators or systems are in place to monitor the health of your community's ecosystems and warn you of problems? What sorts of indicators would you propose to help assess the health of your ecosystem on a regular basis?
- Has there ever been a crisis in your ecosystem like a drought or severe air pollution? What changes did you or your community make to adapt to this crisis? Has this behavior continued? What would inspire you to change your behavior or join an effort to better manage your ecosystem? Does it take a crisis to motivate change?
- What groups or institutions have a significant interest in how your local ecosystem is managed? How do these interests intersect or differ? What are the ways that you could influence or make your values known to these groups or institutions?

Who Is Responsible for Earth's Ecosystems?

- People in developed countries like the United States on average consume much more than people in developing countries. How does this affect our responsibility for ecosystems?
- How do you feel about having a responsibility to people in distant communities to take care of our local ecosystems? Do we have a responsibility to help conserve ecosystems far from our own communities? Why or why not?
- Do you derive spiritual or religious benefits from the beauty of nature? If those ecosystems you think are most beautiful were irreparably damaged or disappeared, how would your life be affected?
- What role do faith-based organizations have in the debate on how ecosystems should be managed?
- What changes could you make in your consumption levels and buying practices to decrease the pressures and demands on ecosystems?
- How can you help encourage business and governments to engage in and support sustainable practices?

Our dominance of Earth's productive systems gives us enormous responsibilities, but great opportunities as well. Human demands on ecosystems have never been higher, and yet these demands are likely to increase dramatically, especially in developing countries, as rising populations mean more and more people seeking better lives. Our understanding of ecosystems has never been greater, and yet even amid an abundance of data we are often confronted with how little we really know about the natural world around us.

THE CHALLENGE FOR THE FUTURE: THE MILLENNIUM ECOSYSTEM ASSESSMENT

The added information provided by the Millennium Ecosystem Assessment (MA)—a new international, scientific effort to determine the capacity and condition of ecosystems globally—will help us better understand our ecosystems.

> "It is impossible to devise effective environmental policy unless it is based on sound scientific information. While major advances in data collection have been made in many areas, large gaps in our knowledge remain. In particular, there has never been a comprehensive global assessment of the world's major ecosystems. The planned Millennium Ecosystem Assessment, a major international collaborative effort to map the health of our planet, is a response to this need. It is supported by many governments, as well as UNEP, UNDP, FAO, and UNESCO. I call on Member States to help provide the necessary financial support for the Millennium Ecosystem Assessment and to become actively engaged in it."
> *—Kofi A. Annan, Secretary-General, United Nations*

The MA will produce an information- and data-rich Internet site and a series of edited volumes and technical reports documenting the scientific findings. In addition, a set of "Policymaker Summaries" target at specific audiences will be produced and a major investment will be made in briefings and workshops to fully communicate the findings to the target audiences. The MA will establish networks of experts; develop and disseminate methods, tools, and data; and stregthen the expertise and stature of individuals and institutions undertaking integrated ecosystem assessments in governments, the private sector, academia, and civil society. The information provided through the MA will inform decisions today. But the strengthened institutions will inform decisions well into the future.

The challenge for the 21st century, then, is to understand the vulnerabilities and resilience of ecosystems, so that we can find ways to reconcile the demands of human development with the tolerances and capacities of nature. International institutions, national governments, local communities, research centers, businesses, and private organizations all must take an ecosystem approach in the policies they pursue, the projects they undertake, and own day-to-day operations.

SECTION 2: TAKING A CLOSER LOOK

AGROECOSYSTEMS

Earth on Edge, Video Part 1: Sustaining the Wealth of the U.S. Prairies

In Part 1 of *Earth on Edge*, Bill Moyers travels to Kansas where Charlie Melander is defying the conventions of contemporary farming practices by trying to use America's rich farmland in a way that prevents its loss to pollution and erosion. The land his family has plowed for three generations was virgin soil until the 1850s, an untouched storehouse of minerals and nutrients anchored by the prairie grass. When farmers broke the sod and tilled the ground, the land was exposed to drought and wind. In less than two centuries, over one-third of the topsoil has blown away and half the nutrients have been exhausted. The Midwestern farmland is continuing to loose topsoil at the rate of 7 tons per acre per year. Melander decided he was part of the problem and started making changes in how he farms the land—drastically cutting back on pesticide and herbicide use, tilling in narrow strips instead of upturning entire fields, and reintroducing animals his land.

But he's bucking the tide. Heavy advertising by the companies that sell soil additives like herbicides and fertilizers, along with government subsidies for their use, have distorted the economics of modern agriculture. They provide a disincentive for sustainable farming. "I maintain that we could change our environment almost overnight if suddenly we said we'll reward less fuel usage, less herbicide usage, less fertilizer usage," Melander tells Moyers.

"Why should I care about how you farm out here, as long as I get the food I need?" Moyers asks. "The equation's not that simple," Melander answers, explaining that a cost of current farming practices is polluted water and the prospect of eroded fields that won't bear crops for future generations. "Whether you like it or not, you're going to be affected by what we do or don't do," he cautions.

Exploring Your Links to Agroecosystems

1 What factors do you consider in selecting food? Do you select any of your food on the basis of how it is grown or produced? Are you willing to pay more for food grown without pesticides or insecticides? Why or why not?

2 Why do you think organic food is more expensive? How can ordinary customers get access to such food at a reasonable cost? How can you support farmers and fishers who are committed to organic sustainable harvests?

3 Has farmland in or near your community been converted to housing developments, shopping centers, roads, or other developments? What benefits has this conversion brought? What costs? Will these changes affect your food supply or recreational oppportunities in the next 20 years?

TAKING STOCK OF AGROECOSYSTEMS

Highlights

- Food production has more than kept pace with global population growth. On average, food supplies are 24% higher per person than in 1961, and real prices are 40% lower.
- Agriculture faces an enormous challenge to meet the food needs of an additional 1.7 billion people over the next 20 years.
- Agroecosystems cover more than one-quarter of the global land area, but almost three-quarters of the land has poor soil fertility and about one-half has steep terrain, constraining production.
- While the global expansion of agricultural area has been modest in recent decades, intensification has been rapid, as irrigated area increased, fallow time has decreased, and the use of purchased inputs and new technologies has grown and is producing more output per hectare.
- About 85 percent of the world's agricultural land contains areas degraded by erosion, salinization, compaction, nutrient depletion, biological degradation, or pollution over the last 50 years. About 34% of all agricultural land contains areas only lightly degraded, 43% contains moderately degraded areas, and 9% contains strongly or extremely degraded areas. The extent of agricultural soil degradation raises questions about the long-term capacity of agroecosystems to produce food.

Conditions and Changing Capacity

Food Production Condition: Good, Capacity: Decreasing
Since 1970, livestock products have tripled and crop outputs have doubled, a sign of rising incomes and living standards. Food production, which was worth US$1.3 trillion in 1997, is likely to continue to increase significantly as demand increases. Nonetheless, soil degradation is widespread and severe enough to reduce productivity on about 16% of agricultural land, especially cropland in Africa and Central America and pastures in Africa. Global inputs and new

technologies may offset this decline in the foreseeable future, but regional differences are likely to increase.

Water Quality Condition: Poor, Capacity: Decreasing
Production intensification has limited the capacity of agroecosystems to provide clean freshwater, often significantly. Both irrigated and rainfed agriculture can threaten downstream water quality by leaching fertilizers, pesticides, and manure into groundwater or surface water. Irrigated agriculture also risks both soil and water degradation through waterlogging and salinization, which decreases productivity. Salinization is estimated to reduce farm income worldwide by US$11 billion each year.

Water Quantity Condition: Fair, Capacity: Decreasing
Irrigation accounts for 70% of the water withdrawn from freshwater systems for human use. Only 30–60% is returned for downstream use, making irrigation the largest net user of freshwater globally. Although only 17% of agroecosystems depend on irrigation; irrigated area increased 72 percent from 1966 to 1996. Competition with other kinds of water use, especially for drinking water and industrial use, will be stiffest in developing countries, where populations and industries are growing fastest.

Biodiversity Condition: Poor, Capacity: Decreasing
Agricultural land, which supports far less biodiversity than natural forests, has expanded primarily at the expense of forest areas. As much as 30% of the potential area of temperate, subtropical, and tropical forests has been lost to agriculture through conversion. Intensification also diminishes biodiversity in agricultural areas by reducing the space allotted to hedgerows, copses, or wildlife corridors and by displacing traditional varieties of seeds with modern high-yield but uniform crops. Nonetheless, certain practices, including fallow periods and shade cropping, can encourage diversity as well as productivity.

Carbon Storage Condition: Fair, Capacity: Mixed
In agricultural areas the amount of carbon stored in soils is nearly double that stored in the crops and pastures that the soils support. Still, the share of carbon stored in agroecosystems (about 26–28% of all carbon stored in terrestrial systems) is about equal to the share of land devoted to agroecosystems (28% of all land). Agricultural emissions of both carbon dioxide and methane are increasing because of conversion to agricultural uses from forests or woody savannas, deliberate burning of crop stubble and pastures to control pests or promote fertility, and paddy rice cultivation.

FRESHWATER SYSTEMS
Earth on Edge, Video Part 2: Working for Water, Working for Human Welfare in South Africa

In South Africa the problem is water scarcity—an unintended consequence of human behavior. European colonists in South Africa preferred a forested landscape to the country's natural low-growing vegetation, and they scattered seeds for pine and eucalyptus. Today, forests of these invasive trees are a threat to the human population, competing for water in an arid climate by soaking up billions of gallons that once filled mountain streambeds. Five years ago the government decided the trees had to go and trained 40,000 previously unemployed people to cut down thousands of trees to restore the precious water that flows from the mountains to the rivers. These environmentalists with chainsaws have already had a positive impact on increasing the flow of rivers in the Cape of Good Hope.

The human species has had a profound impact on water the world over, and it is a resource that is critical to all life. Since 1940, human water consumption has quadrupled—much of it to irrigate farms to provide a sufficient food supply for the growing population. Noted hydropology expert, Melanie Stiassny, explains that governments around the world subsidize farmers to build irrigation systems, but inefficient irrigation systems often deliver only half the irrigated water to the crops and waste the rest. When water supplies dry up, land is severely degraded, or rivers become too polluted, the population has to move on. Habiba Gitay, an expert on climate change, says, "We've already seen in certain parts of the world that you've got conflicts occurring over water rights."

Exploring Your Links to Freshwater Systems

1 How healthy is the stream, river, or lake closest to where you live? Does it support a range of fish, insects, and other aquatic life?
2 The U.S. Clean Water Act assesses the quality of the nation's freshwater bodies based on whether they are fishable and swimmable. Does your nearby stream or river meet these criteria?
3 Estimate how much water you use in a week, in a month. Find a water bill and see how well you estimated your water use.
4 What would inspire you to decrease your water use? Think of ways that you can cut your consumption of water: one idea is to take a 5-minute shower instead of a 10-minute shower. Think of five more.

TAKING STOCK OF FRESHWATER SYSTEMS

Highlights

- Although rivers, lakes, and wetlands contain only 0.01% of the world's freshwater and occupy only 1% of Earth's surface, the global value of freshwater services is estimated in the trillions of US dollars.
- Dams have had the greatest impact on freshwater ecosystems. The number of large dams has increased sevenfold since the 1950s and now impound 14% of the world's runoff.
- Almost 60% of the world's largest 227 rivers are strongly or moderately fragmented by dams, diversions, or canals.
- In 1997, 7.7 million metric tons of fish were caught from lakes, rivers, and wetlands, a production level estimated to be at or above maximum sustainable yield for these systems.
- Freshwater aquaculture contributed 17 million metric tons of fish in 1997. Since 1990, freshwater aquaculture has more than doubled its yield and now accounts for 60% of global aquaculture production.
- Half the world's wetlands are estimated to have been lost in the 20th century, as land was converted to agriculture and urban areas, or filled to combat diseases such as malaria.
- At least 1.5 billion people depend on groundwater as their sole source of drinking water. Overexploitation and pollution in many regions of the world are threatening groundwater supplies, but comprehensive data on the quality and quantity of this resource are not available at the global level.

Conditions and Changing Capacity

Food Production Condition: Good, Capacity: Mixed
At the global level, inland fisheries landings have been increasing since 1984. Most of this increase has occurred in Asia, Africa, and Latin America. In North America, Europe, and the former Soviet Union, landings have declined, while in Oceania they have remained stable. The increase in landings has been maintained in many regions by stocking and by introducing nonnative fish. The greatest threat for the long-term sustainability of inland fisheries is the loss of fish habitat and the degradation of the aquatic environment.

Water Quality Condition: Poor, Capacity: Decreasing
Even though surface water quality has improved in the United States and Western Europe in the past 20 years (at least with respect to phosphorus concentrations), worldwide conditions appear to have degraded in almost all regions with intensive agriculture and large urban or industrial areas. Algal blooms and eutrophication are being documented more frequently in most inland water systems, and water-borne diseases from fecal contamination of surface waters continue to be a major cause of mortality and morbidity in the developing world.

Water Quantity Condition: Fair, Capacity: Decreasing
The construction of dams has helped provide drinking water for much of the world's population, increased agricultural output through irrigation, eased transport, and provided flood control and hydropower. Between 1900 and 1995, withdrawals increased sixfold, more than twice the rate of population growth. Many regions of the world have ample water supplies, but currently almost 40% of the world's population experience serious water shortages. With growing populations, water scarcity is projected to grow dramatically in the next decades. On almost every continent, river modification has affected the natural flow of rivers to a point where many no longer reach the ocean during the dry season. This is the case for the Colorado, Huang-He (Yellow), Ganges, Nile, Syr Darya, and Amu Darya rivers.

Biodiversity Condition: Bad, Capacity: Decreasing
The biodiversity of freshwater ecosystems is much more threatened than that of terrestrial ecosystems. About 20% of the world's freshwater fish species have become extinct, threatened, or endangered in recent decades. Physical alteration, habitat loss and degradation, water withdrawal, overexploitation, pollution, and the introduction of nonnative species all contribute to declines in freshwater species. Amphibians, fish, and wetland-dependent birds are at high risk in many regions of the world.

FOREST ECOSYSTEMS
Earth on Edge, Video Part 3: Forests of British Columbia, Canada

Peacefully and productively resolving the conflicts of competing agendas is one of the great environmental challenges that face the world's population. Traveling to Vancouver, British Columbia, Moyers' team tells the story of an experimental collaboration involving one of Canada's biggest timber companies, MacMillan Bloedel (now owned by Weyerhauser). Environmental protesters halted the clear cutting of old-growth cedar, hemlock and fir in Clayoquot Sound, but when the logging stopped, so did the potential for jobs for Canada's native people, who are known as the First Nations. This economic conflict gave rise to a new collaboration. Working together, MacMillan Bloedel and First Nations, with support from environmental groups like Greenpeace and the Sierra Club, have formed a new company called Iisaak (which means respect in the Native language) to harvest trees in a way that mimics the natural process and allows the ancient rainforests and the wildlife they support to survive. Strategies like using helicopters to fly timber out instead of carving up the forest with roads and cutting trees selectively are more costly in the short-term. But if these methods prove economically viable, the logging and the forest will be sustainable for the long-term. Logger Jake Van Dort finds honor in the new approach. "We're not just going out and raping and pillaging the whole place," he says, "we're going through with some care, you know, and some thought."

Exploring Your Links to Forest Ecosystems

1 Look around the room and identify items made of wood. Should we consider decreasing our wood consumption? If so, what would the impact be? What would we use instead? Could we do without? What would that mean?
2 Would you be willing to pay more for wood that was certified as sustainably harvested? If so, how would you let your local business and policy makers know of your decision?
3 Growing wood on a plantation is in some ways an efficient use of land—plantations yield lots of wood per acre. However, plantations support less biodiversity than natural forests. Does the conversion of a natural forest to a commercial plantation involve trade-offs that you consider acceptable?
4 Is there a plan to maintain the health of the trees in your city? If trees on the street where you live or in a nearby forest were cut down, what impact would that have on your life?

TAKING STOCK OF FOREST ECOSYSTEMS

Highlights

- Forests cover about 25% of the world's land surface, excluding Greenland and Antarctica. Global forest cover has been reduced by at least 20% since preagricultural times, and possibly by as much as 50%.
- Forest area has increased slightly since 1980 in industrial countries, but has declined by almost 10% in developing countries. Tropical deforestation probably exceeds 130,000 km^2 per year.
- Less than 40% of forests globally are relatively undisturbed by human action. The great majority of forests in the industrial countries, except Canada and Russia, are reported to be in "semi-natural" condition or converted to plantations.
- Many developing countries today rely on timber for export earnings. At the same time, millions of people in tropical countries still depend on forests to meet their every need.
- The greatest threats to forest extent and condition today are conversion to other forms of land use and fragmentation by agriculture, logging, and road construction. Logging and mining roads open up intact forest to pioneer settlement and to increases in hunting, poaching, fires, and exposure of flora and fauna to pest outbreaks and invasive species.

Conditions and Changing Capacity

Fiber Production Condition: Good, Capacity: Increasing
Fiber production has risen nearly 50% since 1960 to 1.5 billion cubic meters annually. In most industrial countries, net annual tree growth exceeds harvest rates; in many other regions, however, more trees are removed from production forests than are replaced by natural growth. Fiber scarcities are not expected in the foreseeable future. Plantations currently supply more than 20% of industrial wood fiber, and this contribution is expected to increase. Harvesting from natural forests will also continue, leading to younger and more uniform forests.

Water Quality and Quantity
Condition: Fair, Capacity: Decreasing
Forest cover helps to maintain clean water supplies by filtering freshwater and reducing soil erosion and sedimentation. Deforestation undermines these processes. Nearly 30 percent of the world's major

watersheds have lost more than three-quarters of their original forest cover. Tropical montane forests, which are important to watershed protection, are being lost faster than any other major forest type. Forests are especially vulnerable to air pollution, which acidifies vegetation, soils, and water runoff. Some countries are protecting or replanting trees on degraded hillslopes to safeguard their water supplies.

Biodiversity Condition: Poor, Capacity: Decreasing
Forests, which harbor about two-thirds of the known terrestrial species, have the highest species diversity and endemism of any ecosystem, as well as the highest number of threatened species. Many forest-dwelling large mammals, half the large primates, and nearly 9 percent of all known tree species are at some risk of extinction. Significant pressures on forest species include conversion of forest habitat to other land uses, habitat fragmentation, logging, and competition from invasive species. If current rates of tropical deforestation continue, the number of all forest species could be reduced 4-8%.

Carbon Storage Condition: Fair, Capacity: Decreasing
Forest vegetation and soils hold almost 40% of all carbon stored in terrestrial ecosystems. Forest regrowth in the northern hemisphere absorbs carbon dioxide from the atmosphere, currently creating a "net sink" whereby absorption rates exceed respiration rates. In the tropics, however, forest clearance and degradation are together a net source of carbon emissions. Expected growth in plantation area will absorb more carbon, but likely continuation of current deforestation rates will mean that the world's forests remain a net source of carbon dioxide emissions and a contributor to global climate change.

Woodfuel Production
Condition: Fair, Capacity: Unknown
Woodfuels account for about 15% of the primary energy supply in developing countries and provide up to 80% of total energy in some countries. Use is concentrated among the poor. Woodfuel collection is responsible for much local deforestation in parts of Asia, Africa, and Latin America, although two-thirds of all woodfuel may come from roadsides, community woodlots, and wood industry residues, rather than forest sources. Woodfuel consumption is not expected to decline in coming decades, despite economic growth, but poor data make it difficult to determine the global supply and demand.

GRASSLAND ECOSYSTEMS
Earth on Edge, Video Part 4: Sustaining the Steppe—The Future of Mongolia's Grasslands

In Mongolia, the story is not different vested interests in conflict over resources, but individual families competing for pastureland. On the vast plains of Asia, herding has been a way of life for centuries and ancient techniques of migration enabled grazing pastures to restore and regenerate over seasons. Today, as families strive toward a more settled and prosperous life, they raise larger goat herds closer to markets to meet the demand for cashmere but the vegetation cannot withstand the assault. The thinning grass no longer protects the topsoil, which blows away with the persistent Mongolian wind.

Maria Fernandez Gimenez , a rangeland economist from the University of Arizona, has spent years studying grasslands in Mongolia. She sees trouble ahead for the land and the people, explaining "you have a downward cycle of decreasing mobility and increasing overuse and conflicts over access to pasture." Without some kind of intervention, the pastures could be exhausted within ten years, according to some scientists. As is clear from what happened recently, when a Mongolian dust storm blew particulates across China and all the way to the mainland United States, what happens in Mongolia has implications elsewhere.

Exploring Your Links to Grassland Ecosystems

1 What are some examples, in our country, where an old way of life was more sustainable than a newer more technological process? How do we balance the needs and demands of a growing, changing population with the needs of the people elsewhere and the health of the land itself?
2 How do we balance the desires and needs for people to have better lives with the limits of an ecosystem?
3 If your diet includes meat, was the meat in your last meal from an animal raised in a feedlot situation or on an open range? Does it make a difference to you? What effects are cattle ranchers having on US rangelands?
4 Fire is essential to the healthy functioning of most grassland and forest ecosystems. Yet sometimes fires get out of control and destroy homes as well as many acres of forests. If you were managing Yellowstone Park, what would you do if a fire broke out?

TAKING STOCK OF GRASSLAND ECOSYSTEMS

Highlights

- Grasslands, which cover 40% of Earth's surface, are home to almost a billion people, half of them living on susceptible drylands.
- Agriculture and urbanization are transforming grasslands. Some North American prairies are already nearly 100% converted to farms and urban areas. Road-building and human-induced fires also are changing the extent, composition, and structure of grasslands.
- All of the major foodgrains—corn, wheat, oats, rice, barley, millet, rye, and sorghum—originate in grasslands. Wild strains of grasses can provide genetic material to improve food crops and to help keep cultivated varieties resistant to disease.
- Grasslands attract tourists willing to travel long distances and pay safari fees to hunt and photograph grassland fauna. Grasslands boast some of the world's greatest natural phenomena: major migratory treks of large herds of wildebeest in Africa, caribou in North America, and Tibetan antelope in Asia.
- As habitat for biologically important flora and fauna, grasslands make up 19% of the Centers of Plant Diversity, 11% of Endemic Bird Areas, and 29% of ecoregions considered outstanding for biological distinctiveness.

Conditions and Changing Capacity

Food Production Condition: Fair, Capacity: Decreasing
Many grasslands today support high livestock densities and substantial meat production, but soil degradation is a mounting problem. Soil data show that 20% of the world's susceptible drylands, where many grasslands are located, are degraded. Overall, the ability of grasslands to support livestock production over the long term appears to be declining. Areas of greatest concern are in Africa, where livestock densities are high, and some countries already show decreases in meat production.

Biodiversity Condition: Fair, Capacity: Decreasing
Regional data for North America document marked declines in grassland bird species and classify 10–20% of grassland plant species in some areas as non-native. In other areas, such as the Serengeti in Africa, population levels of large grassland herbivores have not changed significantly in the past two decades.

Carbon Storage Condition: Good, Capacity: Decreasing
Grasslands store about one-third of the global stock of carbon in terrestrial ecosystems. That amount is less than the carbon stored in forests, even though grasslands occupy twice as much area. Unlike forests, where vegetation is the primary source of carbon storage, most of the grassland carbon stocks are in the soil. Thus, the future capacity of grasslands to store carbon may decline if soils are degraded by erosion, pollution, overgrazing, or static rather than mobile grazing.

Recreation Condition: Good, Capacity: Decreasing
People worldwide rely on grasslands for hiking, hunting, fishing, and religious or cultural activities. The economic value of recreation and tourism can be high in some grasslands, especially from safari tours and hunting. Some 667 protected areas worldwide include at least 50% grasslands. Nonetheless, as they are modified by agriculture, unbanization, and human-induced fires, grasslands are likely to lose some capacity to sustain recreation services.

COASTAL ECOSYSTEMS
Earth on Edge, Video Part 5: Scaffolds of Living Stone—Brazil

Brazil is as lush as Mongolia is barren, but it, too, faces the pressure of competing human demands on natural resources. The coastal reef at Tamandare is a magnet for tourists and for fishers, but the beauty and the bounty of its waters are at risk. Marine biologists Beatrice Ferreira and Mauro Maida persuaded the Brazilian government to close off 1,000 acres of this endangered reef in hopes that the coral and marine life would recover. And it worked. "After only eight months of closure you could see an increase four times the number of octopus, four times the number of lobster," says Maida. But while the government invested $4 million in this project, developers are investing $800 million to turn the region into a tourist mecca like Cancun, which will threaten the underwater ecology.

Marine biologist Carl Safina explains that marine life is threatened the world over. "I hear buzzers going off all around me," he says, "80% of the world's fisheries are either at their very limit of what they can produce without going into major long-term decline, or are already in major decline, or depleted."

Worldwide, 70% of all reefs are at risk; 60% of all mangroves have already been destroyed. The rest are disappearing at a rate of 5% a year.

Exploring Your Links to Coastal Ecosystems

1 Do you live or vacation near in a coastal area? What does the ecosystem mean to you? How has the ecosystem changed over time? What are the pressures from fishing and tourism on the coastal area?
2 Even if you don't live in or near a coastal area, in what ways are these ecosystems important to your life?

TAKING STOCK OF COASTAL ECOSYSTEMS

Highlights

- Almost 40% of the world's population lives within 100 km of a coastline, an area that accounts for only 22% of Earth's land mass.
- Population increase and land conversion for development, agriculture, and aquaculture are reducing mangroves, coastal wetlands, seagrass areas, and coral reefs at an alarming rate.
- Fish and shellfish provide about one-sixth of the animal protein consumed by people worldwide. A billion people, mostly in developing countries, depend on fish for their primary source of protein.
- Coastal ecosystems have already lost much of their capacity to produce fish because of overfishing, destructive trawling techniques, and destruction of nursery habitats.
- Rising pollution levels are associated with increasing use of synthetic chemicals and fertilizers.
- Global data on extent and change of key coastal habitats are inadequate. Coastal habitats are difficult to assess from satellite data because areas are small and often submerged.

Conditions and Changing Capacity

Food Production Condition: Fair, Capacity: Decreasing
Global marine fish production has increased sixfold since 1950, but the rate of increase annually for fish caught in the wild has slowed from 6% in the 1950s and 1960s to 0.6% in 1995–96. The catch of low-value species has risen as the harvest from higher-value species has plateaued or declined, masking some effects of overfishing. Approximately 75% of the major fisheries are fully fished or overfished, and fishing fleets have the capacity to catch many more fish than the maximum sustainable yield. Some of the recent increase in the marine fish harvest comes from aquaculture, which has more than doubled in production since 1990.

Water Quality Condition: Fair, Capacity: Mixed
As the extent of mangroves, coastal wetlands, and seagrasses declines, coastal habitats are losing their pollutant-filtering capacity. Increased frequency of harmful algal blooms and hypoxia indicates that some coastal ecosystems have exceeded their ability to absorb nutrient pollutants. Although some industrial countries have improved water quality by reducing input of certain persistent organic pollutants, chemical pollutant discharges are increasing overall as agriculture intensifies and industries use new synthetic compounds. Furthermore, while large-scale marine oil spills are declining, oil discharges from land-based sources and regular shipping operations are increasing.

Biodiversity Condition: Fair, Capacity: Decreasing
Indicators of habitat loss, disease, invasive species, and coral bleaching all show declines in biodiversity. Sedimentation and pollution from land are smothering some coastal ecosystems, and trawling is reducing diversity in some areas. Commercial species such as Atlantic cod, five species of tuna, and haddock are threatened globally, along with several species of whales, seals, and sea turtles. Invasive species are frequently reported in ports and enclosed seas, such as the Black Sea, where the introduction of Atlantic comb jellyfish caused the collapse of fisheries.

Recreation Condition: Good, Capacity: Unknown
Tourism is the fastest-growing sector of the global economy, accounting for $3.5 trillion in 1999. Some areas have been degraded by the tourist trade, particularly coral reefs, but the effects of tourist traffic on coastal ecosystems at a global scale are unknown.

Shoreline Protection
Condition: Poor, Capacity: Decreasing
Human modification of shorelines has altered currents and sediment delivery to the benefit of some beaches and detriment of others. Coastal habitats with natural buffering and adaptation capacities are being modified by development and replaced by artificial structures. Thus, the impact from storm surges has increased. Furthermore, rising sea levels, projected as a result of global warming, may threaten some coastal settlements and entire small island states.

URBAN ECOSYSTEMS

Urban areas provide goods and services of enormous value, including human habitat, transportation networks, and a variety of income opportunities. Cities are also centers of natural resource consumption and generators of enormous amounts of wastes.

The concept of urban areas as ecosystems is new and controversial. Measuring urban areas is not an exact science. Administrative boundaries of cities generally are not reliable indicators of urban ecosystem boundaries and urban areas are not sharply delineated but blend into suburbs and then rural areas. Generally the densities of population and infrastructure determine the physical extent of urban ecosystems. According to one recent estimate, urban ecosystems cover about 4% of the world's surface (WRI et al. 2000:24). And global urban populations are projected to nearly double by 2030 to 5.1 billion (UN Population Division 1996).

Goods and Services Provided by Urban Green Spaces

Air Quality Enhancement and Temperature Regulation

Urban ecosystems are highly modified, with buildings, streets, parking lots impenetrably covering the soil. Large areas of heat-absorbing surfaces, like asphalt, combined with a city's building density and high energy use lead to a "heat island" effect. Temperatures in heavily urbanized areas may be 0.6–1.3°C warmer than in rural areas (Goudie 2000:350). Higher temperatures, in turn, make cities incubators for smog.

Green space within cities—lawns and parks, forests, cultivated land, wetlands, lakes, streams—significantly lower overall temperatures and thus reduce energy consumption and air pollution (Lyle and Quinn 1991:106, citing Bryson and Ross 1972:106). The evaporation process of a single large tree consumes heat energy and releases a great deal of moisture into the air. Urban trees and forests remove nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and particulate matter. Trees in Chicago, for example, have been estimated to remove 5,575 tons of air pollutants per year, providing air cleansing worth more than US$9 million (Nowak 1994:71, 76). Forests in the Baltimore/Washington region remove 17,000 tons of pollutants per year, providing a service valued at $88 million (American Forests 1999:5). Urban lakes and streams also help moderate seasonal temperature variations.

Open space and tree cover vary widely in cities, depending on the natural environment and land use. In the United States, an analysis of more than 50 cities found that urban tree cover ranged from 0.4% in Lancaster, California to 55% in Baton Rouge, Louisiana (Nowak et al. 1996:51).

Urban Tree Cover in Selected Cities

Tree cover in cities varies because of differences both in management and in the natural environment.

City	Tree Cover (%)
Baton Rouge, LA	55
Waterbury, CT	45
Portland, OR	42
Dallas, TX	28
Denver, CO	26
Los Angeles, CA	15
Chicago, IL	11
Lancaster, CA	.04

Source: Nowak et al. 1996.

Biodiversity and Wildlife Habitat

Cities can support a relatively wide variety of plants and animals, including both native species and nonnative species that have adapted to the urban landscape. Urban parks and other green spaces are critical to migratory species and provide wildlife corridors. Though these corridors are often too fragmented to afford animals sufficient area to maintain diverse populations, in many North American urban areas, deer and small herbivores such as squirrels are prevalent. Muskrats and beavers may be widespread in urban water areas, and some smaller predators like bats, opossum, raccoon, coyote, fox, mink, and weasels adapt well to the habitat changes wrought by development (Adams 1994:57–65).Many urban streams are so polluted or their riparian zone so substantially reduced and cleared of vegetation, that only the most pollution-tolerant species survive. Yet urban rivers also offer some of the greatest potential for biodiversity restoration. For example, in 1957 London's Thames was virtually devoid of fish in one stretch, but by 1975 efforts to improve the biological conditions were rewarded with the return of 86 different species of marine and freshwater fish (Douglas 1983:137).

Bird diversity in urban areas may provide a good indicator of environmental quality, since birds require differentiated habitat and are influenced by air and aquatic pollution through the food chain. For example, a 1993 survey of Washington, D.C. bird species richness identified 115 species—an estimate that agreed closely with totals from surveys decades earlier, and was almost as high as the number found in larger, surrounding counties. This suggests that Washington, D.C.—perhaps because parks and low to moderate density residential areas cover 70% of the metropolitan area—is providing diverse, good-quality habitat for birds (U.S. National Biological Survey 2000).

Storm-Water Control

Urban forests, wetlands, and streamside vegetation buffer storm-water runoff, control pollution, help recharge natural groundwater reservoirs, and minimize flooding in urban areas. In contrast, buildings and roads cover much urban land with impervious surfaces and eliminate vegetation that provides natural water storage capacity. It is estimated that forests in the Baltimore/Washington area save the region more than $1 billion—money that would otherwise have to be spent on storm-water retention ponds and other systems to intercept runoff (American Forests 1999:2). Unfortunately, in most cities worldwide, trees are a resource at risk. Since the 1970s, three major U.S. metropolitan areas—Seattle, Baltimore/Washington, and Atlanta—have lost more than a third of their heavy tree cover (Smith 1999:35).

Food and Fiber Production

Urban agriculture includes aquaculture, orchards, and livestock and crops raised in backyards and vacant lots, on rooftops and roadsides, and on small suburban farms (UNCHS 1996:410). Urban and periurban agriculture is estimated to involve 800 million urban residents worldwide (FAO 1999). In Kenya and Tanzania, 2 of 3 urban families are engaged in farming; in Taiwan, more than half of all urban families are members of farming associations; in Bangkok, Madrid, and San Jose, California, up to 60% of the metropolitan area is cultivated (Smit and Nasr 1992:142; Chaplowe 1998:47). Urban agriculture provides subsistence opportunities and income enhancement for the poor and offers a way to recycle the high volumes of wastewater and organic solid wastes that cities produce.

Recreational Opportunities and Aesthetic Havens

Trees provide visual relief, privacy, shade, and wind breaks. Trees and shrubs can reduce cities' typically high noise levels; a 30-m belt of tall dense trees combined with soft ground surfaces can reduce noise by 50% (Nowak and Dwyer 1996:471). Parks provide urban dwellers with easy access to recreational opportunities and places to relax—an enormously valuable service where open space and escape from asphalt are often at a premium. Some urban parks, lakes, and rivers are also tourist attractions and enhance the value of downtown areas.

Managing Urban Areas as Ecosystems

Because the science of urban ecology is in its infancy, there is a dearth of data on the "green" elements of cities. Lack of planning and budgeting for the care of green spaces is another problem. Many cities lack systematic tree-care programs, and little attention is paid to the effects of soil conditions, restrictions to root growth, droughts caused by the channeling off of rain, the heat island effect, and the lack of undergrowth (Sampson 1994:165).

Managing urban consumption and its impact on neighboring ecosystems is a tremendous challenge. The total area required to sustain a city is called its "ecological footprint" (Rees 1992). It is estimated that a city with a population of 1 million in Europe requires, every day, an average of 11,500 tons of fossil fuels, 320,000 tons of

Exploring Your Links to Urban Ecosystems

1. How has the green space characteristics of your urban area changed over time? Are there notably fewer green spaces and trees than before? Is there a tree-care program in your city?
2. Are you aware of the birds and small animals that live in your area? Have you noticed a change in the wildlife in your area?
3. Are there areas for food and fiber production in your city? Are there farmer markets? How far are the farms from your city center?
4. Is there a plan to maintain the health of the trees in your city? If trees on the street where you live or in a nearby forest were cut down, what impact would that have on your life? What if new trees or a forest were planted?
5. Has farmland in or near your community been converted to housing developments, shopping centers, roads, or other developments? What benefits has this conversion brought? What costs? Will these changes affect your food supply or recreational opportunities in the next 20 years?

BOTTOM LINE FOR URBAN ECOSYSTEMS

Urban ecosystems are dominated by human activities and the built environment, but they contain vital green spaces that confer many important services. These range from removing air pollution and absorbing runoff to producing food through urban agriculture. Urban forests, parks, and yards also soften the urban experience and provide invaluable recreation and relaxation. The science of urban ecosystems is new and there is no comprehensive data showing urban ecosystem trends on a global basis. However, more localized data show that loss of urban tree cover, and the consequent decline of urban green spaces, is a widespread problem. The rapid growth in urban populations worldwide adds to the mounting stress on urban ecosystems. Continued decline in the green elements of urban ecosystems will erode the other values—economic, educational, and cultural. Urban population increases heighten the need to incorporate the care of city green spaces as a key element in urban planning.

water, and 2,000 tons of food, much of which is produced outside the city. The same city produces 300,000 tons of wastewater, 25,000 tons of CO_2, and 1,600 tons of solid waste (Stanners and Bordeau 1995:263). Any attempt to improve the sustainability of urban ecosystems must identify ways for cities to exist in greater equilibrium with surrounding ecosystems.

The good news is that urban areas present tremendous opportunities for greater efficiencies in energy and water use, housing, and waste management. Strategies that encourage better planning, mixed-use development, urban road pricing, and integrated public transportation can dramatically lessen the environmental impacts of billions of people. For example, the million or more brownfields (urban land parcels that once supported industry or commerce but lie abandoned or contaminated) that scar cities worldwide offer the chance to create new green spaces or lessen congestion and development pressure on remaining green areas (Mountford 1999).

SECTION 3: BACKGROUND INFORMATION

How Much Do We Consume?

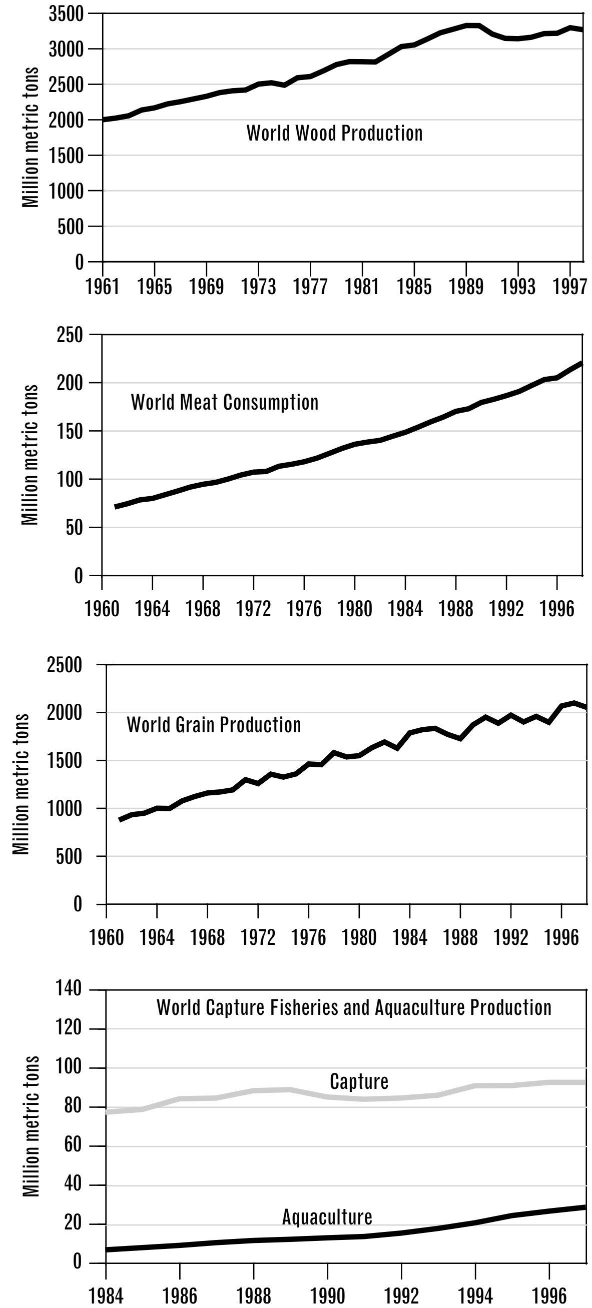
Humans consume goods and services for many reasons: to nourish, clothe, and house ourselves, certainly. But we also consume as part of a social compact, since each community or social group has standards of dress, food, shelter, education, and entertainment that influence its patterns of consumption beyond physical survival (UNDP 1998:38-45).

At its best, consumption is a tool for human development—one that opens opportunities for a healthy and satisfying life, with adequate nutrition, employment, mobility, and education. Poverty is marked by a lack of consumption, and thus a lack of these opportunities. At the other extreme, wealth can—and often does—lead to excessive levels of material and nonmaterial consumption.

In spite of its human benefits, consumption can lead to serious pressure on ecosystems. Consumption harms ecosystems directly through overharvesting of animals or plants, mining of soil nutrients, or other forms of biological depletion. Ecosystems suffer indirectly through pollution and wastes from agriculture, industry, and energy use, and also through fragmentation by roads and other infrastructure that are part of the production and transportation networks that feed consumers.

Consumption of the major commodities that ecosystems produce directly—grains, meat, fish, and wood—have increased substantially in the last four decades and will continue to increase as the global economy expands and world population grows. Plausible projections of consumer demand in the next few decades suggest a marked escalation of impacts on ecosystems (Matthews and Hammond 1999:5).

- Global wood consumption has increased 64% since 1961. More than half of the 3.4 billion cubic meters of wood consumed annually is burned for fuel; the rest is used in construction and for paper and a variety of other wood products. Demand for lumber and pulp is expected to rise between 20 and 40% by 2010. Forest plantations produce 22% of all lumber, pulp, and other industrial wood; old-growth and secondary-growth forests provide the rest (Matthews and Hammond 1999:8, 31; Brown 1999:41).
- World cereal consumption has more than doubled in the last 30 years, and meat consumption has tripled since 1961 (Matthews and Hammond 1999:7). Some 34% of the world's grain crop is used to feed livestock raised for meat (USDA 2000). A crucial factor in the rise in grain production has been the more than fourfold increase in fertilizer use since 1961 (Matthews and Hammond 1999:14). By 2020, demand for cereals is expected to increase nearly 40%, and meat demand will surge nearly 60% (Pinstrup-Andersen et al. 1999:11).



Sources: FAO 1999; FOA 2000.

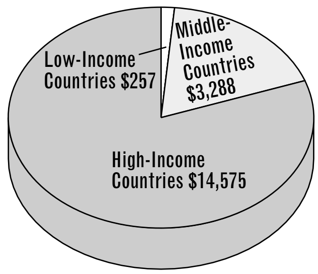
- The global fish catch has grown more than sixfold since 1950 to 122 million metric tons in 1997. Three-fourths of the global catch is consumed directly by humans as fresh, frozen, dried, or canned fish and shellfish. The remaining 25% are reduced to fish meal and oil, which is used for both livestock feed and fish feed in aquaculture. Demand for fish for direct consumption is expected to grow some 20% by 2010 (FAO 1999:7, 82; Matthews and Hammond 1999:61).

The Unequal Geography of Consumption

While consumption has risen steadily worldwide, there remains a profound disparity between consumption levels in wealthy nations and those in middle- and low-income nations.

- On average, someone living in a developed nation consumes twice as much grain, twice as much fish, three times as much meat, nine times as much paper, and eleven times as much gasoline as someone living in a developing nation (Laureti 1999:50, 55).

Global Share of Private Consumption, 1997 (in billions)



Consumers in high-income countries—about 16% of the world's population—accounted for 80% of the money spent on private consumption in 1997—$14.5 trillion of the $18 trillion total. By contrast, purchases by consumers in low-income nations—the poorest 35% of the world's population—represented less than 2% of all private consumption. The money spent on private consumption worldwide (all goods and services consumed by individuals except real estate) nearly tripled between 1980 and 1997 (World Bank 1999:44, 226).

TRADE-OFFS: LAKE VICTORIA'S ECOSYSTEM BALANCE SHEET

Rarely do resource managers or policy makers fully weigh the various trade-offs among ecosystem goods and services. Why? In some cases, lack of information is the obstacle. Typically, not much is known about the likely impact of a particular decision on nonmarketed ecosystem services such as water purification or storm protection. Or, if such information does exist, it may not include estimates of the economic costs and benefits of the trade-offs. In other cases the obstacle is institutional. A government's Ministry of Agriculture naturally focuses primarily on its mission of food production and lacks the expertise or mandate to

Disparities in Consumption: Annual per Capita Consumption in Selected High-, Medium-, and Low-Income Nations

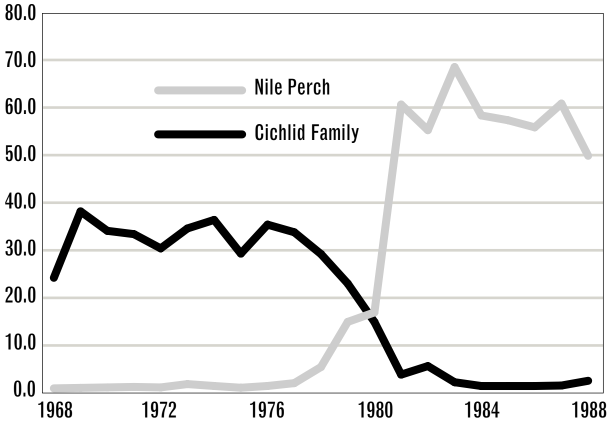
Country	Total Value of Private Consumption* (1997)	Fish (kg) (1997)	Meat (kg) (1998)	Cereals (kg) (1997)	Paper (kg) (1998)	Fossil Fuels (kg of oil equivalent) (1997)	Passenger Cars (per 1,000 people) (1996)
United States	$21,680	21.0	122.0	975.0	293.0	6,902	489.0
Singapore	$16,340	34.0	77.00	159.0	168.0	7,825	120.0
Japan	$15,554	66.0	42.0	334.0	239.0	3,277	373.0
Germany	$15,229	13.0	87.0	496.0	205.0	3,625	500.0
Poland	$5,087	12.0	73.0	696.0	54.0	2,585	209.0
Trinidad/Tobago	$4,864	12.0	28.0	237.0	41.0	6,394	94.0
Turkey	$4,377	7.2	19.0	502.0	32.0	952	55.0
Indonesia	$1,808	18.0	9.0	311.0	17.0	450	12.2
China	$1,410	26.0	47.0	360.0	30.0	700	3.2
India	$1,166	4.7	4.3	234.0	3.7	268	4.4
Bangladesh	$780	11.0	3.4	250.0	1.3	67	0.5
Nigeria	$692	5.8	12.0	228.0	1.9	186	6.7
Zambia	$625	8.2	12.0	144.0	1.6	77	17.0

*Adjusted to reflect purchasing power, accounting for currency and cost of living differences (the "purchasing power parity" approach).

Sources: Total Private Consumption (except China and India): World Bank 1999:Table 4.11; (fish) Laureti 1999:48-55; (meat) WRI et al. 2000a:Agriculture and Food Electronic Database; (paper) WRI et al. 2000b: Data Table ERC.5; (fossil fuels) WRI et al. 2000b: Data Table ERC.2; (passenger cars) WRI et al. 2000b: Data Table ERC.5.

Trading Biodiversity for Export Earnings

Percentage Contribution to Lake Victoria Fish Catch (Kenya only), 1968–1988



Source: Achieng 1990:20, citing Fisheries Department of Kenya, *Statistical Bulletin.*

consider impacts of its actions on water quality, carbon sequestration, or coastal fisheries, for instance.

The example of Africa's Lake Victoria illustrates how profound and unpredictable trade-offs can be when management decisions are made without regard to how the ecosystem will react. Lake Victoria, bounded by Uganda, Tanzania, and Kenya, is the world's largest tropical lake and its fish are an important source of food and employment for the region's 30 million people. Before the 1970s, Lake Victoria contained more than 350 species of fish from the cichlid family, of which 90% were endemic, giving it one of the most diverse and unique assemblages of fish in the world (Kaufman 1992:846–847, 851). Today, more than half of these species are either extinct or found only in very small populations (Witte et al. 1992:1, 17).

The collapse in the lake's biodiversity was caused primarily by the introduction of two exotic fish species, the Nile perch and Nile tilapia, which fed on and outcompeted the cichlids for food. By 1983, Nile perch made up almost 70% of the catch, with Nile tilapia and a native species of sardine making up most of the balance (Achieng 1990:20). In addition, land-use changes in the watershed dumped pollution and silt into the lake, increasing its nutrient load which caused algal blooms and low oxygen levels in deeper waters—a process called eutrophication

Although the introduced fishes devastated the lake's biodiversity, they did not destroy the commercial fishery. In fact, fish production and its economic value rose. Today, the Nile perch fishery produces some 300,000 metric tons of fish (FAO 1999), earning $280–$400 million in the export market—a market that did not exist before the perch was introduced (Kaufman 2000). The local communities that had depended on the native fish for decades, however, did not benefit from the success of the Nile perch fishery, mostly because Nile perch and tilapia are caught with gear that local fishermen couldn't afford. And, because most of the Nile perch and tilapia are shipped out of the region, the local availability of fish for consumption has declined. In fact, while tons of perch find their way to diners as far away as Israel and Europe, there is evidence of protein malnutrition among the people of the lake basin (Kaufman 2000).

The sustainability of the Nile perch fishery is also a concern. Overfishing and eutrophication are major threats to the fishery, and the stability of the entire aquatic ecosystem—so radically altered over a 20-year span—is in doubt. The ramifications of the species introductions can even be seen in the watershed surrounding Lake Victoria. Drying the perch's oily flesh to preserve it requires firewood, unlike the cichlids, which could be air-dried. This has increased pressure on the area's limited forests, increasing siltation and eutrophication, which, in turn, has further unbalanced the precarious lake ecosystem (Kaufman 1992:849–851; Kaufman 2000).

In sum, introducing Nile perch and tilapia to Lake Victoria traded the lake's biodiversity and an important local food source for a significant—although perhaps unsustainable—source of export earnings. When fisheries managers introduced these species, they unknowingly altered the balance of goods and services the lake produced and redistributed the economic benefits flowing from them. Knowing the full dimensions of these trade-offs, would they make the same decision today?

ARE WE ALTERING EARTH'S BASIC CHEMICAL CYCLES?

Tracking the changes in Earth's chemical cycles—carbon, nitrogen, and water cycles—is essential to understanding the condition of ecosystems. These cycles serve as the basic metabolism of the biosphere, affecting how every ecosystem functions and linking them all on a global level. Human-induced changes in these cycles can alter climate patterns and affect the availability of basic nutrients and water that sustain plant and animal life.

The Carbon Cycle

Carbon dioxide (CO_2) concentrations in the atmosphere rose 30% from 1850 to 1998, from 285 parts per million to 366 parts per million (IPCC 2000:4) This rise is largely the result of increased CO_2 emissions from burning fossil fuels. However, changes in land use and management have also played a major role by releasing carbon that had been stored in vegetation and soil. About 33% of the carbon that has accumulated in the atmosphere over the past 150 years is a result of deforestation and changes in land use (IPCC 2000:4).

Climate models tell us that rising carbon concentrations in the atmosphere will alter Earth's climate, affecting precipitation, land and sea temperatures, sea level, and storm patterns. Changing climate will also affect the rate of greenhouse gas emissions from some ecosystems. Models suggest that a warmer climate in the arctic will elevate the rate of decomposition of the vast peat reserves in tundra and taiga ecosystems, increasing the release of CO_2 into the atmosphere.

Elevated CO_2 concentrations lead to a "fertilizer effect"—increasing the growth rate of some plants and changing some of the chemical and physical characteristics of their cells. This in turn will alter the composition of biological communities. PAGE researchers estimated that a warmer climate could raise cereal production by 5% in mid- to high-latitude regions (mostly developed countries) but might decrease cereal yields in low-latitude regions by 10% (particularly in African developing countries).

The Nitrogen Cycle

Human influence on the global nitrogen cycle is even more profound and already more biologically significant. The production and use of fertilizers, burning of fossil fuels, and land clearing and deforestation also increases—far beyond natural levels—the amount of nitrogen available to biological systems (Vitousek et al. 1997:5). This added nitrogen has caused serious problems, particularly in freshwater and coastal ecosystems where excess nitrogen stimulates growth of algae, sometimes depleting available oxygen to the point where other aquatic organisms suffocate, a process known as eutrophication.

The Freshwater Cycle

The scale of human impact on freshwater cycles is also massive. Humans currently take more than half of accessible freshwater runoff, and by 2025, demand is projected to increase to more than 70% of runoff (Postel et al. 1996:7, 787). A substantial amount—70%—of the water currently withdrawn from all freshwater sources is used for agriculture (WMO 1997:9). Shifting water from freshwater systems to agroecosystems increases crop production, but at significant cost to downstream ecosystems and downstream users. As much as 60% of water withdrawn from rivers is lost to downstream uses (Postel 1993:56; Seckler 1998:4).

Some of the water diverted from rivers or directly consumed does return to rivers but, typically, it carries pollution in the form of agricultural nutrients or chemicals, or human or industrial waste.

Global Cycles, Global Impacts

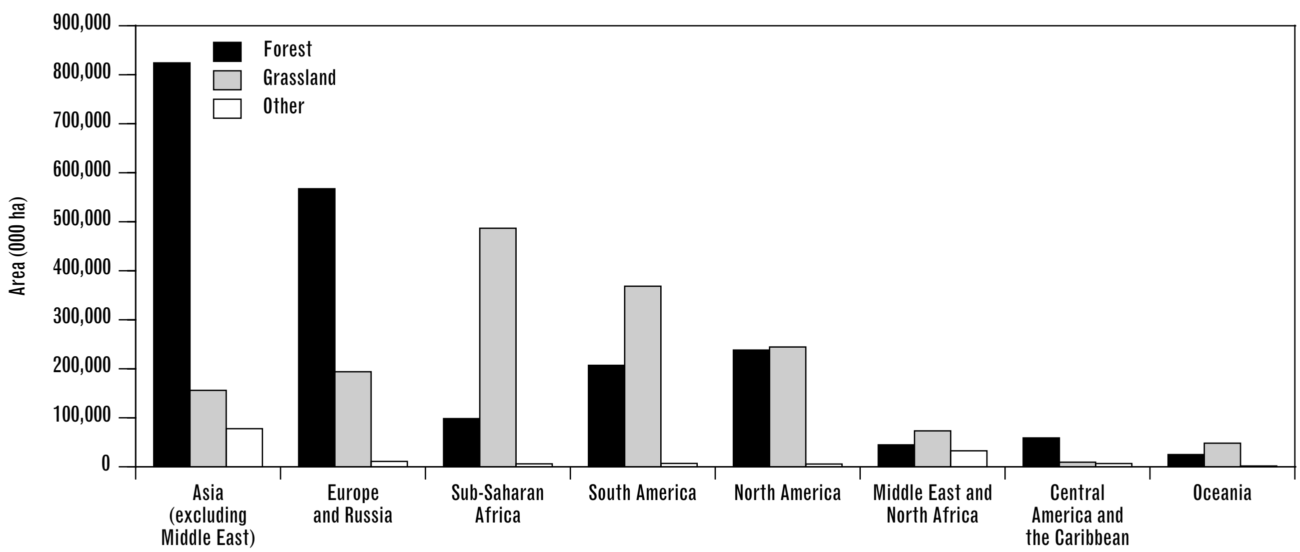
The importance of these global cycles to the functioning of ecosystems cannot be overstated. There is no question that sound management of Earth's ecosystems requires changes in the use of resources at local levels, but local level changes will not suffice. Some of the most important management decisions regarding Earth's ecosystems—decisions that will have the most profound influence on the future ability of ecosystems to meet human needs—can only be made at regional and even global levels. To make those decisions, it is vital that we examine and assess the condition of ecosystems at those levels.

DOMESTICATING THE WORLD: CONVERSION OF NATURAL ECOSYSTEMS

Since the dawn of settled agriculture, humans have been altering the landscape to secure foood, create settlements, and pursue commerce and industry. Croplands, pastures, urban and surburban areas, industrial zones, and the area taken up by roads, reservoirs, and other major infrastructure all represent conversion of natural ecosystems.

These transformations of the landscape are the defining mark of humans on Earth's ecosystems, yielding most of the food, energy, water, and wealth we enjoy, but they also represent a major source of ecosystem pressure.

Area Converted by Region



Source: WRR calculations.

Conversion alters the structure of natural ecosystems, and how they function, by modifying their basic physical properties—their hydrology, soil structure, and typography—and their predominant vegetation. This basic restructuring changes the complement of species that inhabits the ecosystem and disrupts the complex interactions that typified the original ecosystem. In many cases, the converted ecosystem is simpler in structure and less biologically diverse. In fact, habitat loss from conversion of natural ecosystems represents the primary driving force in the loss of biological diversity worldwide (Vitousek et al. 1997:495).

Historically, expansion of agriculture into forest, grasslands, and wetlands has been the greatest source of ecosystem conversion. Within the last century, however, expansion of urban areas with their associated roads, power grids, and other infrastructure, has also become a potent source of land transformation.

- Worldwide, humans have converted approximately 29% of the land area—almost 3.8 million ha—to agriculture and urban or built-up areas (WRR calculations).

- Agricultural conversion to croplands and managed pastures has affected some 3.8 million ha—roughly 26% of the land area. All totaled, agriculture has displaced one-third of temperate and tropical forests and one-quarter of natural grasslands. Agricultural conversion is still an important pressure on natural ecosystems in many developing nations; however, in some developed nations agricultural lands themselves are being converted to urban and industrial uses (WRR calculations).

- Urban and built-up areas now occupy more than 471 million ha—about 4% of land area. Almost half the world's population—some 3 billion people—live in cities. Urban populations increase by another 160,000 people daily, adding pressure to expand urban boundaries (UNEP 1999:47). Suburban sprawl magnifies the effect of urban population growth, particularly in North America and Europe. In the United States, the percentage of people living in urban areas increased from 65% of the nation's population in 1950 to 75% in 1990, but the area covered by cities roughly doubled in size during the same period (PRB 1998).

- Future trends in land conversion are difficult to predict, but projections based on the United Nations' intermediate-range population growth model suggest that an additional one-third of the existing global land cover could be converted over the next 100 years (Walker et al. 1999:369).

REFERENCES

Urban Ecosystems

Adams, L. W. 1994. Urban Wildlife Habitats: A Landscape Perspective. Minneapolis: University of Minnesota Press.

American Forests. 1999. Regional Ecosystem Analysis Chesapeake Bay Region and the Baltimore-Washington Corridor: Calculating the Value of Nature. Washington, D.C.: American Forests. 22 March 1999.

Bolund, P. and S. Hunhammar. 1999. Ecosystem services in urban areas. Ecological Economics 29:293–301.

Bryson, R. and J. Ross. 1972. The climate of the city. Pp. 52–76 in Urbanization and Environment. T. Detwyler and M. Marens, eds. Belmont, CA: Duxbury Press.

Chaplowe, S. G. 1998. Havana's popular gardens: Sustainable prospects for urban agriculture. *The Environmentalist* 18(1):47–57.

Douglas, I. 1983. *The Urban Environment*. London, UK: Edward Arnold.

Folke, C., Å. Jansson, J. Larsson and R. Costanza. 1997. Ecosystem appropriation of cities. *Ambio* 26(3):167–172.

Food and Agriculture Organization of the United Nations (FAO). 1999. Urban and Peri-Urban Agriculture. Report to the FAO Committee on Agriculture (COAG). Online at: http://www.fao.org /unfao/bodies/COAG/ COAG15/X0076e.htm.

Goudie, A. 2000. *The Human Impact on the Natural Environment*. Cambridge, MA: MIT Press.

Kowarik, I. 1990. Some responses of flora and vegetation to urbanization in Central Europe. Pp. 45–74 in *Urban Ecology: Plants and Plant Communities in Urban Environments*. H. Sukopp and S. Hejn´y, eds. The Hague: SBP Academic Publishing.

Lyle, J. and R. D. Quinn. 1991. Ecological corridors in urban southern California. In *Wildlife Conservation in Metropolitan Environments: Proceedings of a National Symposium on Urban Wildlife*. L. W. Adams and D. L. Leedy, eds. Columbia, MD: National Institute for Urban Wildlife.

Mountford, D., U.S. Environmental Protection Agency. 1999. Personal Communication. E-mail. 12 March.

Nowak, D. J. 1994. Air pollution removal by Chicago's urban forest. Pp. 63–81 in *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*. E. G. McPherson, D. J. Nowak and R. A. Rowntree, eds. Gen. Tech. Report NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Nowak, D. J. and J. F. Dwyer. 1996. Urban Forestry. Pp. 470–472 in *McGraw-Hill Yearbook of Science and Technology*. New York: McGraw-Hill.

Nowak, D. J., R. A. Rowntree, E. G. McPherson, S. M. Sisinni, E. R. Kerkmann and J. C. Stevens. 1996. Measuring and analyzing urban tree cover. *Landscape and Urban Planning* 36:49–57.

Rees, W. E. 1992. Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment and Urbanization* 4(2):121–130.

Sampson, R. N. 1994. Making cities safe for trees. Pp. 157–170 in *The City as a Human Environment*. D. G. LeVine and A. C. Upton, eds. Westport, CT: Praeger Publishers.

Smit, J. and J. Nasr. 1992. Urban Agriculture for sustainable cities: Using wastes and idle land and water bodies as resources. *Environment and Urbanization* 4(2):141–154.

Smith, D. 1999. The case for greener cities. *American Forests Magazine* Autumn 1999:35–37.

Stanners, D. and P. Bordeau, 1995. *Europe's Environment: The Dobris Assessment*. Copenhagen: European Environment Agency.

U.N. Centre for Human Settlements (Habitat). 1996. *An Urbanizing World: Global Report on Human Settlements*. Oxford, UK: Oxford University Press.

U.N. Population Division (UNPD). 1996. *Urban and Rural Areas 1950–2030. (The 1996 Revision)*. On Diskette. New York: UNPD.

U.S. Census Bureau. 1995. Urban and Rural Definitions. Online at: http://www.census.gov/population/ censusdata/urdef.txt.

U.S. Department of the Interior, U.S. Fish and Wildlife Service, U.S. Department of Commerce and Bureau of the Census. 1997. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Washington, D.C.: U.S. Government Printing Office.

U.S. National Biological Survey. 2000. Washington D.C. Project Birdscape. Online at: http://www.im.nbs.gov/ birdscap/birdscap .html.

World Bank. 2000. *World Development Indicators 2000*. Washington, D.C.: The World Bank.

World Resources Institute in collaboration with the United Nations Environment Programme and the United Nations Development Programme and the World Bank. 1998. *World Resources 1998–99*. New York: Oxford University Press.

How Much Do We Consume?

Brown, C. 1999. Global Forest Products Outlook Study: Thematic Study on Plantations. Working Paper No. GFPOS/WP/03 (Draft). Rome: FAO.

Food and Agriculture Organization of the United Nations (FAO). 2000. FAOSTAT databases. Online at: http:// apps.fao.org/.

Food and Agriculture Organization of the United Nations (FAO). 1999. *The State of World Fisheries and Aquaculture, 1998*. Rome: FAO.

Laureti, E. 1999. Fish and Fishery Products: World Apparent Consumption Statistics Based on Food Balance Sheets. FAO Fisheries Circular No. 821, Revision 5. Rome: FAO.

Matthews, E. and A. Hammond. 1999. *Critical Consumption Trends and Implications: Degrading the Earth's Ecosystems*. Washington, D.C.: World Resources Institute.

Pinstrup-Andersen, P., R. Pandya-Lorch and M. Rosegrant.

1999. *World Rood Prospects: Critical Issues for the Early Twenty-First Century*. Washington, D.C.: International Food Policy Research Institute.
U.N. Development Programme (UNDP). 1998. *Human Development Report 1998*. New York: UNDP.
U.S. Department of Agriculture (USDA). 2000. Production, Supply and Distribution Database. Online at: http://usda.mannlib.cornell.edu/data-sets/international/93002/PSDFAQ.TXT.
World Bank. 1999. *World Development Indicators 1999*. Washington, D.C.: The World Bank.

Trade-Offs: Lake Victoria's Ecosystem Balance Sheet

Achieng, A. P. 1990. The impact of the introduction of Nile perch, Lates niloticus (L.) on the fisheries of Lake Victoria. *Journal of Fish Biology* 37(Supplement A):17–23.
Food and Agriculture Organization of the United Nations (FAO). 1999. FISHSTAT. Version 2.19 by Yury Shatz. Rome: FAO.
Kaufman, L. 1992. Catastrophic change in species-rich freshwater ecosystems: The lessons from Lake Victoria. *BioScience* 42(11):846–858.
Kaufman, L., Boston University Marine Program. 2000. Personal Communication. Interview. 7 February.
Witte, F., T. Goldschmidt, J. Wanink, M. van Oijen, K. Goudswaard, E. Witte-Mass and N. Bouton. 1992. The destruction of an endemic species flock: Quantitative data on the decline of the haplochromine cichlids of Lake Victoria. *Environmental Biology of Fishes* 34:1–28.

Are We Altering Earth's Basic Chemical Cycles?

Intergovernmental Panel on Climate Change (IPCC) (R. Watson, I. N., B. Bolin, N. Ravindranath, D. Verardo, and D. Dokken, eds.). 2000. *Land Use, Land-Use Change, and Forestry*. Cambridge, UK: Cambridge University Press.
Vitousek, P. M., C. M. D'Antonio, L. L. Loope and R. Westbrooks. 1997. Introduced species: A significant component of human-caused global change. New Zealand Journal of Ecology 21(1):1–16.
Postel, S. L., G. C. Daily and P. R. Ehrlich. 1996. Human appropriations of renewable fresh water. Science 271:785–788.
World Meteorological Organization (WMO). 1997. Comprehensive Assessment of the Freshwater Resources of the World. Geneva: WMO.
Seckler, D., U. Amarasinghe, D. Molden, R. de Silva and R. Barker. 1998. World Water Demand and Supply, 1990 to 2025: Scenarios and Issues. Research Report 19. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Domesticating the World: Conversion of Natural Ecosystems

Loveland, T. R., B. C. Reed, J. F. Brown, D. O. Ohlen, Z. Zhu, L. Yang and J. Merchant. 2000. Development of a Global Land Cover Characteristics Database and IGBP DISCover from 1 km AVHRR data. *International Journal of Remote Sensing* 21(6):1303–1330. Online at: http://edcdaac.usgs.gov/glcc/glcc.html.
National Oceanic and Atmospheric Administration-National Geophysical Data Center (NOAA-NGDC). 1998. Stable lights and radiance calibrated lights of the world CD-ROM. NOAA-NGDC: Boulder, CO. Online at: http://julius.ngdc.noaa.gov:8080/production /html/BIOMASS/night.html. (December 1998).
Population Reference Bureau (PRB). 1998. United States Population Data Sheet. Washington, D.C.: PRB.
U.N. Environment Programme (UNEP). 2000. *Global Environmental Outlook 2000*. London: Earthscan Publications Ltd.
Walker, B. H., W. L. Steffen and J. Langridge. 1999. Interactive and integrated effects of global change on terrestrial ecosystems. Pp. 329–374 in *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems*. B. Walker, W. Steffen, J. Canadell and J. Ingram, eds. Cambridge: Cambridge University Press.
World Wildlife Fund, US (WWF-US). 1999. Ecoregions database. Unpublished Database. Washington, D.C.: WWF-US.

Earth on Edge features five case studies of ecosystems and the people whose lives depend on them, whose actions have degraded them, and who hold the power to restore them. They showcase the trade-offs inherent in ecosystem management, the diverse influences of governments and economic policies, the value of improved information about ecosystem conditions, and the vital importance of community participation for ecosystem health.

Sustaining the Wealth of the U.S. Prairies: The story of the Kansas Prairie is a story about us, our country and what we inadvertently squandered on our way to wealth and power. Intensive farming techniques have steadily exploited and wasted this magnificent inheritance over the last two centuries. When devastation hit in the 1930s, we thought we had fixed it, again. But today erosion is worse than ever and the wells are drying up.

Working for Water, Working for Human Welfare in South Africa: Nonnative plants have invaded 10 million hectares of South Africa—the legacy of two centuries of careless introduction of these plants in commerce. These plants deprive the country of precious water, reduce biodiversity, obstruct rivers, and increase soil erosion. South Africa's multiagency response, the Working for Water programme, has hired thousands of poor, disadvantaged citizens to remove invading woody species while earning a living wage and new skills.

Forests of British Columbia: The fight to save the coastal rain forests of British Columbia is much more than the usual environmental action: this is a high-stakes, eco-marketing campaign in the interests of an ancient treasure. The trees are thousands of years old, but the tactics are pure twenty-first century. The results are a compromise; a timber company and its once combative critics are now working together—learning from each other *and* the ecosystem that they are trying to protect.

Sustaining the Steppe—The Future of Mongolia's Grasslands: Nomadic Herders have grazed large numbers of livestock on Mongolia's grassland steppe for thousands of years. Rotating their animals over vast shared pastures in complex seasonal patterns, Mongolian herders have anchored their country's economy without degrading its ecosystems. In the face of recent political and economic change, however, these sustainable practices may be disappearing. Can Mongolia balance indigenous herding traditions with the forces of urbanization, modernization, and the transition to a market economy?

Scaffolds of Living Stone—Brazil: The city of Recife is named after the reefs that line the coast nearby, reaching south and north around the Atlantic shoulder of Brazil. But the accumulated pressures of human population and development—pollution, over-fishing, mangrove destruction to build beach houses or shrimp pens for aquaculture—are slowly reducing the reefs and the fish life. The specific story of Recife stands for the threats to coastal ecosystems everywhere.