CHAPTER 8

# Global Problems and Local Concerns

Social and environmental problems often spill over national boundaries. Many of the issues described in earlier chapters—risk management in the fragile lands (chapter 4), races for property rights in water and land (chapter 5), urban pollution (chapter 6), and conflict (chapter 7)—have international ramifications. Dealing with them requires the same kind of institutional apparatus described in chapter 3: problems must be detected and diagnosed, and interests must be balanced within and across borders. However, there is one big difference: at the global level, there is no central authority to enforce agreements. Nations have to devise ways to keep themselves on agreed paths.

This chapter cannot treat in detail the long, varied, and growing list of challenges that require international cooperation: transboundary river basin management; international fisheries management; control of infectious diseases; mitigation of acid rain; and prevention of armed conflict and terrorism, to name a few. Instead, it draws general lessons from the experience with some environmental problems regarding the design and development of institutions that can handle more difficult transnational issues.

Chapter 8 features progress on two transnational environmental problems: protecting the stratospheric ozone layer, and mitigating acid rain in Europe. It applies these lessons to two fundamental but unresolved sustainability issues that are the subjects of controversy and emerging global environmental conventions: mitigating and adapting to climate change, and conserving biodiversity. (A third issue, desertification, is addressed in the context of chapter 4.) Though usually characterized as environmental issues, these problems have causes and solutions with deep social and political roots, and lessons for nonenvironmental global problems.

## Designing institutions to solve global problems

Who would have thought that leaky refrigerators, fire extinguishers, and aerosol spray cans could seriously damage the entire biosphere? The story of how stratospheric ozone depletion was diagnosed as a problem, and how the global community organized to address it, illustrates how *adaptive, learning institutions* can successfully address global issues.

Refrigerators began using chlorofluorocarbons (CFCs) around 1930.[1] By 1970 the world used about 1 million tons of these substances each year as coolants, as propellants in aerosol cans, and for manufacturing. In that year, James Lovelock used recently invented techniques to detect trace amounts of CFC in the atmosphere over London. His request for a grant to measure CFC concentrations over the Atlantic was denied: "One reviewer commented that even if the measurement succeeded, he could not imagine a more useless bit of knowledge."

Lovelock persisted, though, and showed that CFCs were detectable far from land. Four years later, chemists F. Sherwood Rowland and Mario Molina realized that even tiny concentrations of CFCs could, theoretically, erode the stratospheric ozone layer that shields life from ultraviolet radiation, an insight that won them the 1995 Nobel Prize in chemistry. It was known, too, that CFCs had a long lifetime in the atmosphere and that increased exposure to ultraviolet radiation would increase the risk of skin cancer. Although a definitive cause-and-effect relationship had not yet been demonstrated,

circumstantial evidence was strong enough in the early 1980s to support a precautionary approach to the threat of ozone depletion. The Vienna Convention (1985) committed the nations of the world to addressing the problem, but imposed no obligations.

Meanwhile, scientists had been monitoring stratospheric ozone since the 1920s in a widening global network that extended to Antarctica in 1957. A scientist at the British Antarctic Station, noticing declining ozone readings in the late 1970s, published definitive data by 1984. Shortly thereafter, dramatic satellite images of the Antarctic ozone "hole" captured public attention. This deepening evidence prompted the Montreal Protocol of 1987, an outgrowth of the Vienna Convention, to impose obligations on developed countries to reduce the use of ozone-depleting substances. The Montreal Protocol also set up panels to assess the impacts of ozone depletion and the technology and economics of mitigating ozone-depleting substances.

By 1990 there was firmer evidence of a causal impact of chlorine and bromine compounds on ozone. In that year the London Protocol to the Vienna Convention took effect. Under this protocol, developing countries agreed to take on obligations, with a grace period, and developed countries underwrote a trust fund to assist them.

The process remains dynamic. Two more amendments to the Vienna Convention have been adopted. Technical panels, involving multistakeholder cooperation, have helped identify technological approaches to phasing out ozone-depleting substances. More than $1.3 billion have been committed to help developing countries. The result: a foreseeable reduction in atmospheric concentrations of ozone-depleting substances and an eventual recovery of the ozone layer.

The problem of protecting the global ozone layer was, for a variety of reasons, easier to tackle than other global problems. The production and use of ozone-depleting substances is not central to any economy—unlike greenhouse gases, whose production is deeply embedded in the energy and transport sectors. It has been easy to find less harmful substitutes for most substances, at modest cost. The political economy of reaching agreement has also been favorable. At the national level, the wealthy industrial nations responsible for most production were also those at the greatest risk from skin cancer, in part because ozone depletion is far more severe at temperate than tropical latitudes. And the corporations that produced most ozone-depleting substances also produced most substitutes.

The record of success in tackling this problem provides both hope and inspiration for other global initiatives. It also shows the key components in global problem-solving:

- Pick up signals of the problem and agree on its nature.
- Build local capacity and international networks to support adaptive learning.
- Reconcile domestic and international interests.

These components are explored in detail below, together with an emerging fourth:

- Harness decentralized mechanisms to establish incentives for socially responsible actions.

### *Pick up signals of the problem and agree on its nature*

Solving problems requires some consensus on the facts and on the costs and impacts of action (or inaction). The first step is to detect the problem and put it on the public agenda. Initial detection of environmental problems is often by scientists, sometimes drawing serendipitously on information gathered for entirely different purposes. Acid rain, for instance, was taken seriously in Europe only after a Swedish scientist, Svante Odén, in 1967, used data from a long-standing network of precipitation monitors to link foreign emissions to acidic rain in Sweden, and to link the rain to deteriorating surface water quality.[2] But detection is not enough. Especially where dispersed interests need to be mobilized, activists (sometimes including scientists) can put a problem on the public agenda. NGOs such as TI, Global Witness, and Global Forest Watch gather and publicize evidence on corruption and human rights abuse, especially in relation to management of forests and natural resources. In the future, the new Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters may facilitate detection and discussion of environmental and social problems.

The next step is achieving some consensus on the problem's gravity, threats, and potential solutions. At the outset, activists use data to demand action, and defenders of the status quo attack the data and interpretation as inaccurate, incomplete, and biased.

Progress in resolving the issue requires better information and some consensus on the diagnosis. This is not always easy. To understand such problems as acid rain and global warming, we need to understand how thousands of factories and millions of households behave—and how chemicals mix and react across the entire atmosphere. These processes can be understood only through sophisticated simulation models, and the models can be validated only against rich and accurate observations of physical, biological, and social systems. There is scope for honest disagreement on interpreting data and models. And naturally, each stakeholder group will promote interpretations favorable to its own interests. What is needed is a credible, legitimate forum for fostering consensus on diagnosis and action.[3]

Combining credibility and legitimacy in a policy institution is a fine balancing act, especially for global issues. Credibility requires scientific and technical input, insulated as much as possible from political pressures. Legitimacy, by contrast, is properly political. Parties to an international agreement need to legitimate and accept the scientists' interpretations. So do the citizenries who will be asked to comply with the agreement. Mediating institutions need somehow to broker problem analyses that are politically palatable and yet have scientific integrity. How can this be done?

The IPCC is one example. The IPCC was chartered by the World Meteorological Organization and the United Nations Environment Programme (UNEP) to assess the risk of human-induced climate change. It has produced three large assessments, carried out by an international team of volunteer experts, who evaluate and synthesize the vast and sometimes contradictory scientific literature through an elaborate set of working groups, subgroups, and reviews. Because the reports are thick, densely technical documents, attention focuses on distilling summaries for policymakers. Each summary is approved, line by line, by representatives of all IPCC member governments in a forum where scientists can defend their conclusions. The process results in political buy-in to scientific findings. Over the past 10 years, the IPCC's work has contributed greatly to promoting consensus on the nature and causes of climate change.

The World Commission on Dams (WCD) is another pioneering assessment effort, emphasizing social issues. The commission's goals were to review the effectiveness of large dams, to provide a framework for assessing options and decisionmaking processes for water resource development, and to produce guidelines related to all aspects of dam development. Convened by the World Bank and the IUCN, the commission's members represented a broad range of stakeholders. It succeeded in producing a consensus report whose core values and strategic priorities have been widely endorsed. But the informal authorizing environment has resulted in weak engagement of national governments in the result, according to an independent evaluation.[4] And there is less consensus on the WCD's specific recommendations for implementation. It remains to be seen whether the report will be a one-off outcome—or will have initiated a sustained process of learning and engagement.

### *Learning and adapting*

The diagnostic process is most effective when it feeds into an adaptive process of balancing interests, setting goals, taking actions, and learning from results. The Convention on Long-Range Transboundary Air Pollution (CLRTAP) illustrates adaptive learning (box 8.1). This Convention has forged increasingly ambitious agreements among European nations (including economies in transition) on reducing emissions that cause acid rain, eutrophication, ground-level ozone, and other environmental problems. It has done so in part by encouraging the collection, harmonization, and analysis of data on emissions and environmental conditions. This process has fostered communication among policymakers and scientists, facilitated agreement on an operational definition of goals, and promoted a rational, cost-effective approach to achieving those goals.

The CLRTAP and the Montreal Protocol illustrate the appeal of adaptive learning in forging international agreements. Countries are averse to taking on binding commitments when there is great uncertainty about the costs or impacts, about their ability to induce citizens to comply, and about the compliance of other parties. Adaptive learning allows countries—and groups whose behavior is targeted for change—to understand the problem and to acquire confidence in their own ability and others' to deal with it.

Two routes are available:

- One route is through "soft law": nonbinding statements of principles and sometimes targets. By grad-

**Box 8.1**
**An adaptive, learning institution**

The CLRTAP has concentrated mostly on mitigating European pollution, though it includes North American parties. Its first substantive agreement, the Helsinki Protocol (1985), required parties to reduce sulfur emissions by 30 percent relative to those in 1980. Many observers consider this to have been a modest goal. But it established a track record of cooperation that has so far resulted in six subsequent (and increasingly more ambitious) protocols on emissions reductions.

In setting, refining, and implementing reduction targets, CLRTAP has been aided by the Cooperative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) and the acid-rain modeling group at the International Institute of Applied Systems Analysis (IIASA). EMEP was established in 1977 with a U.N. mandate, but was "adopted" and given permanent funding by CLRTAP in a 1984 protocol. EMEP has worked to compile data on emissions and air quality—and to model atmospheric transport of pollutants. Several reviews by political scientists have pointed to EMEP as catalytic in promoting better understanding of the pollution problems and facilitating agreements on more stringent emissions limits. Over more than a decade, EMEP worked to ensure consistency in data collection and reporting methods among its diverse members.

By 1990 the data were deemed good enough to support a credible simulation model, RAINS, to assess the costs and impacts of alternative emissions reductions scenarios. This model, developed at IIASA, was used by negotiators in setting commitment levels for the Second Protocol on Sulfur Reduction. It and subsequent analyses have shown that the near-term cost of fully meeting environmental goals was unaffordable, facilitating agreement on achievable interim measures.

The process of data-gathering, model-building, and model application facilitated communication among scientists and policymakers, fostering a virtuous cycle of continuous refinement of data and models. This has helped the Convention tackle additional pollutants and provides a basis for all stakeholders to monitor nations' compliance with the protocols, increasing mutual confidence in the Convention. Integrated assessment modeling has now been formally incorporated into EMEP, though it remains based at IIASA.

*Sources:* Jäger and others (2001); Jäger, van Eijndhoven, and Clark (2001); Di Primio (1998); Chayes and Chayes (1995).

ually establishing norms, soft law lays the foundation for negotiation on binding arrangements. Nonbinding but ambitious targets can also encourage experimentation that would be too risky under a binding regime.[5]

- The other route is to start with a binding agreement that is easy to achieve, but that sets up a process that allows parties to learn more about costs and benefits and to build confidence in their partners' behavior and in newly created institutions.

For both routes, the seemingly mundane requirement of reporting can be key.[6] Reporting—for greenhouse gas emissions under the Kyoto Protocol, for consumption of ozone-depleting substances under the Montreal Protocol, or for compliance with labor standards under the International Labour Organisation—deepens domestic understanding of the problem and strengthens external confidence in the country's commitment to compliance.

### *Build local capacity for assessment, negotiation, and action*

How can a hundred or more governments, representing billions of people, forge sustainable agreements that touch those people's lives? These agreements need to balance the diverse interests of groups that cut across national boundaries. International labor standards affect the workers, owners, and customers of low-wage assembly plants. The Montreal Protocol touches multinational and local chemical companies, people who risk developing skin cancer, and poor families that dream of affording a small used refrigerator. Negotiations on climate change affect coal miners, oil companies, Sahelian herders, atoll dwellers, car owners, and wind turbine entrepreneurs.

To work, these agreements must reconcile interests within and between countries. This requires mobilizing concern, and demands for action, among the many who would gain some benefit from the agreement, but who are less vocal than the few who perceive their main interests to be at risk. It thus requires creative ways of framing problems and solutions to increase the perceived congruence of interests, within and across countries. And it often depends on strengthening the capabilities of people and organizations in the developing world to assess options, to negotiate provisions, and to finance and undertake actions.

Bolivia and Costa Rica have countless pressing domestic concerns, yet both have taken the lead in pursuing biodiversity conservation goals with global implications. Their experience illustrates the critical role of networks of experts and policy entrepreneurs in mobilizing domestic concern and finding creative ways to link civil society, domestic policymakers, and global interests. In both countries, research or-

**Box 8.2**
**"Coupling institutions" and policy entrepreneurs in Costa Rica and Bolivia**

In Costa Rica and Bolivia strong communities of policy entrepreneurs have grown around a unique brand of environmental research organization that serves as a site for collaboration and intellectual exchange between national and foreign environmental experts. The Tropical Science Center, The Tropical Agriculture Research and Higher Learning Center, the Organization for Tropical Studies, and the Ecology Institute provide training in tropical ecology. They also facilitate networking among environmental scientists who wish to apply their knowledge toward creating institutions such as environmental laws, agencies, and protected areas. These same experts have taken the lead in building national support for sustainable environmental management, creating environmental education programs in schools and helping to "mainstream" environmental concerns in their societies.

The institutional accomplishments in Bolivia include the world's first debt-for-nature swap, the world's largest forest-based climate mitigation project, and some of the world's most innovative approaches to park management, involving indigenous peoples, NGOs, and local stakeholders. Among Costa Rica's successes are its national park system and innovative explorations of environmental finance, including its environmental services payments system, forest-based carbon offsets, and biodiversity prospecting agreements.

Three characteristics of these research institutions are noteworthy:

- They are physically located in the countries of interest. This is essential for networking and community building among national scientists, and produces a cadre of experts who often assume leadership roles in environmental agencies and NGOs.
- They ensure extensive participation by both domestic and foreign scientists, which encourages international cooperation in support of national goals.
- They are nonpartisan, which facilitates constructive working relationships among experts and reformers associated with diverse political parties—a key ingredient for ensuring that policy reform efforts continue across administrations.

*Source:* Steinberg (2001).

ganizations linking national and international scientists nurtured a group of policy entrepreneurs who could blend scientific knowledge and international financial resources with the domestic political skills and experience needed to usher through and implement major policy reforms (box 8.2). Attuned to ideas from abroad but deeply immersed in domestic social movements and policy debates, these countries have been at the forefront of an impressive record of environmental policy innovations. And they have helped to stimulate national dialogues on environmental quality and sustainable development.

Capacity building of this kind is important for developing countries to assess, negotiate, and implement international agreements. Lacking experts and money, poorer countries are often at a disadvantage in international negotiations. For instance, lower-income countries fielded substantially smaller delegations at the sixth Conference of Parties of the Kyoto Protocol, handicapping their ability to participate in the wide range of simultaneous, technically specialized sessions.[7] And without a pool of experts, it is difficult for these countries to design policies and implement projects. For these reasons, it is important to develop expert networks and organizations within developing countries (and in some cases shared between developing countries)—and sustain them over the long term. It is not enough to assemble teams for temporary assignments.[8]

### *Reconcile domestic and international interests—with commitments and cash*

International agreements are possible because of the overlap between domestic and global interests—and because participating nations agree that the benefits they gain outweigh the costs that they accept. But environmental and social agreements usually involve balancing opposing domestic interests, often supporting a broad constituency of dispersed interests against one that is more narrowly focused but influential. And national compliance is not usually achieved with the simple stroke of an executive pen, requiring instead the cooperation of a multitude of citizens, government officials, corporate leaders, and others. Think, for instance, of the issues surrounding worker rights, pollution, and protection of privately owned wetlands or forests. A nation that agrees to international commitments on these issues has to deploy domestic carrots and sticks to coax its citizens into compliance. However, international agreements themselves can help provide some of those carrots and sticks.

Sometimes, international agreements can be a welcome tool to reinforce domestic legislation and regulation. The Ramsar Convention on wetlands requires that each participant commits to the conservation and sustainable use of at least one wetland site of "international importance." (Almost 1 million square kilometers of wetland are now listed, in both

developed and developing countries.) Listing may restrict the ability of farmers or developers to drain and convert wetlands—or that of factories and waste-treatment plants to pollute them. But these restrictions may also confer domestic benefits such as groundwater recharge and flood prevention, while also providing global benefits such as maintenance of migratory wildlife populations.

Although the Ramsar Convention has little enforcement power, preliminary analysis shows that protection of listed wetlands has improved. This suggests that listing with Ramsar helps strengthen domestic commitments to wetlands protection. Similarly, accession to human rights conventions can strengthen implementation of domestic laws on human rights.[9] The Aarhus Convention, for example, appears to strengthen domestic commitments to freedom of information on environmental issues.

Financial transfers are often designed to align local actions with global interests. Many international agreements recognize that developing countries may be unable to finance their commitments to improve the global environment, even when those commitments provide some domestic benefits. The GEF has approved about $2.7 billion in grants to reduce ozone-depleting substances, mitigate climate change, protect biodiversity, and protect international waters. Depending on how the Kyoto Protocol is implemented, developing countries and economies in transition could get billions of dollars annually in market payments that would promote clean energy technologies.

### *Standards, certification, and performance reporting—inducing socially responsible behavior*

How can society reward people, firms, organizations, and governments that behave well? Locally, a community might patronize merchants who are friendly, civic-minded, and environmentally responsible—and do so happily even if their prices are a bit higher than those of less respectable competitors. Outside the community, the scope for doing this diminishes, as information about reputation thins. Citizens may appeal to the government to regulate or tax bad behavior, and sometimes that works. But it does not always work—it fails at the global scale, or when government is unresponsive. An emerging set of institutions and networks tries to fill this gap by generating information about performance, using that information to set up incentives for socially responsible behavior.

Intentional oil pollution at sea was curbed through clever use of standards and performance reporting. The problem had long been intractable: empty tankers filled their still-oily tanks with water for ballast, then discharged the polluted mix. The 1958 International Convention for the Prevention of Pollution of the Sea by Oil prohibited this practice, but enforcement was impossible on the wide dark seas. A new convention, MARPOL (1978) tackled the problem afresh, requiring that all new ships have a ballast tank separate from the oil tank. Independent verification bodies inspect ships and issue certificates of compliance. Ships find it hard to get insurance without a certificate. The problem was partially solved[10]—though the lack of port facilities for oil disposal remains a problem.[11]

Private firms have great leeway in their choice of production processes. These choices have environmental and social consequences, both local and global. They affect the quantity of industrial and agrochemical pollutants dumped into waterways, the care with which fish and timber are harvested, the treatment of low-wage workers, the release of greenhouse gases. But these choices are generally not easily observable by outsiders.

Systems for environmental and social performance reporting (or certification) might help shift firms toward more socially responsible production processes, for a variety of reasons. Consumers may preferentially patronize more responsible firms—for instance, those that produce sustainable timber or fish products. Communities may apply pressure to firms that flout legal or social norms.[12]

Perhaps most importantly, financial markets may reward companies with good performance indicators. Why? A growing literature suggests that better environmental and social performance is no burden and at best is associated with higher profits.[13] One econometric study found that multinational firms that apply self-imposed higher-than-U.S. standards throughout their global operations had higher market value than otherwise comparable firms.[14] Another study, of 614 U.S. firms, found that a 10 percent reduction in waste generation was associated with a 0.3 percentage point increase in the return on

assets.[15] These associations may be causal: good practices reduce waste of valuable materials, improve worker morale and productivity, smooth community relations, and reduce liability. And it may be that managers who deal well with complex environmental and social issues are also good at other aspects of running a business. Either way, if environmental and social performance is a proxy for profitability, then financial markets will welcome and act on improved information on such performance.

Various initiatives are beginning to publicize information about environmental and social performance—and there is some evidence of firms responding. Indonesia's government-led PROPER program, which instituted audited self-reporting of firms' pollution levels, has now been emulated in China, India, the Philippines, and Vietnam (see World Bank 2000d and Wang and others forthcoming). Nongovernmental evaluation and certification systems are developing quickly. The International Organization for Standardization has formalized certification for environmental management processes—systems that give firms the kind of internal feedback mechanisms that figure prominently throughout this Report. Some NGOs have developed certification systems for timber, labor standards in shoe and apparel assembly, organic food production, and other products and processes.[16] For instance, the NGO-initiated Forest Stewardship Council has set up criteria for sustainable forest management and now accredits private certifiers. By 2001, 25 million hectares of forest (mostly plantation) were certified. Several private investment firms have developed "triple bottom line" rating systems to assess firms' social, environmental, and financial performances. And the Global Reporting Initiative, a UNEP-sponsored organization, is trying to develop auditable standards for environmental and social reporting, analogous to those for financial reporting.

There has been rapid growth in mutual funds and other investment vehicles that screen investments on social and environmental performance. In 1984, $40 billion in professionally managed assets were socially screened; in 2001, $2 trillion, of $19 trillion in professionally managed assets.[17] The growing demand for socially responsible investment and the growing supply of environmental and social performance indicators can interact in a virtuous circle. Better information enables more discerning investment; greater interest in ethical investment elicits better information. Similarly, as certification starts to become the norm in an industry, noncertified products find it harder to compete.

Who sets the standards and defines the indicators—and how? This is crucial to the future of such "bottom-up" approaches to regulation. Already there are disputes about how strictly to set standards for certification. Overly lax standards could defeat the purpose of certification. But so too could overly strict standards, if they are too expensive for firms to adopt and for outsiders to monitor. In logging regulation, overly strict standards can impose high costs on loggers without yielding environmental benefits.[18] This tradeoff is of crucial interest in trade negotiations, especially where developing countries fear that onerous standards would freeze them out of export markets. It is worth considering whether global environmental assessment institutions could serve a role in evaluating potential standards.

Standards and indicators are also being applied to governments. TI assesses corruption in national governments, with ratings that catalyze domestic political pressure for reform and affect private sector investment decisions. It has been credited with helping to spur international efforts to reduce corruption (see chapter 7, box 7.3).[19] The International Monetary Fund (IMF) has recently been promoting standards for reporting basic economic data, such as GDP, inflation, employment, and balance of payments. It has also prepared Codes of Good Practice on Fiscal, Monetary, and Financial Transparency, with the explicit aim of promoting good governance. Countries naturally have different capacities to comply with the standards, and the IMF gives them assistance to upgrade their capabilities. Ultimately, though, markets and the global community may look at progress toward compliance as one indicator of a country's commitment to good governance.

### Conserving biodiversity: Maintaining current services and future options

In a remote corner of Ethiopia a farmer clears woodland for planting. In the process he eliminates one of the few remaining stands of the wild coffee from which all commercial coffee is descended—and which contains genes that protect against leaf rust, a

peril to worldwide coffee production. In the Atlantic Forest of Brazil a prosperous cocoa grower chops down the forest trees that shaded his now-diseased cacao plants, but which also provided habitat for the golden-headed lion tamarin, an endangered species that could be the prime attraction in a future ecotourism industry. In the lowlands of Sumatra large companies convert forests of rich biodiversity to oil palm plantations.

In all these cases, actors pursuing private profit not only threaten biodiversity of global interest—they also damage resources valuable to their neighbors and country. The damage may be immediate and palpable, but sometimes it is hard to measure in financial terms and its full impact may be deferred, since doomed ecosystems can take decades to unravel. That makes it hard to pick up signals of biodiversity damage, difficult to balance diffuse nonmonetary interests against focused profit-driven ones, and challenging to implement policies that shift incentives from degradation toward sustainable use. The complexity of the problem, along with the possibility of irreversible losses, motivates the attention to biodiversity in this chapter.

The message here is that maintaining biodiversity and ecosystem functions is not an agenda solely of wealthy countries, as some hold. To the contrary: biodiversity has a local constituency that values it for economic and noneconomic reasons. But where biodiversity's services do not yield revenues, it can be difficult for those constituencies to protect their environmental assets against liquidation. Poor societies may be unable, by themselves, to finance the option values of ecosystem conservation. The challenge then is to find ways to ally domestic and global interests that support conservation and sustainable use.

### *The scale of the problem*

Ecosystems are being disrupted on a large scale:

- A global satellite survey estimated a pantropical gross deforestation rate of 0.52 percent annually over 1990–2000, or 9.2 million hectares a year, an area the size of Portugal.[20]
- Coral reefs are being lost to bleaching,[21] pollution, and destructive fishing. A worldwide bleaching event in 1998, associated with El Niño, harmed 16 percent of the world's coral reefs, with possibly half damaged irreversibly. Another 32 percent are thought to be threatened over the next 30 years, and 11 percent have already been lost.[22]
- Three-quarters of all fish stocks are being exploited at or above their sustainable limits. Total harvests from capture fisheries have leveled off or declined. Some fisheries, such as the Northwest Atlantic cod, have completely collapsed.[23] In others, depletion of prized predatory fish have led to shifts in ecosystem structure. Almost 15 million square kilometers of ocean bottom have been scraped by ocean trawlers, possibly causing long-lasting damage to bottom-dwelling species.

### *What drives ecosystem degradation?*

People deliberately degrade ecosystems for profit. To reach any kind of social consensus on policies to reduce ecosystem degradation, it is essential to understand the actors involved, and the incentives that drive them. Forest loss, for instance, results largely from conversion to agriculture by small, medium, and large farmers, though logging often plays a crucial catalytic role in providing access and financing for conversion. Until recently, impoverished shifting cultivators were thought to cause much tropical deforestation. While there are localized, poignant examples of poverty-driven deforestation of this type—for instance, in Madagascar (box 8.3)—shifting cultivation appears to account for only a small proportion of the degradation of closed-canopy tropical forests (figure 8.1).[24] Other small and medium farmers account for much of African deforestation, and a small proportion but significant quantity of deforestation in closed forests elsewhere. This is a diverse group, including some subsistence farmers but many commercially oriented and prosperous operators. And large-scale agriculture, including ranches and plantations, accounts for most deforestation in Latin America and Asia. Poverty, therefore, is not the immediate driver of most tropical deforestation, but tropical deforestation can exacerbate the poverty of communities dependent on the forest for their livelihood.

Returns to forest conversion by smallholders are variable but often modest. Often the returns are lower than the option value of the forests (see section titled "Act now to reduce today's emissions") for carbon sequestration alone. Farmers' conversion of Ecuadorian forest has been estimated to yield a present value of $376 to $1,721 a hectare,[25] depending on the proximity to roads and access to credit.[26] In Sumatra, con-

**Box 8.3**
**Poverty and biodiversity in Madagascar**

Madagascar's biodiversity is among the richest and most unusual in the world, an asset difficult to value in monetary terms but with great potential to support ecotourism and perhaps bioprospecting industries. Of its 12,000 plant species, 85 percent are found only on Madagascar. Its 32 endemic lemur species are an attraction for ecotourists. Alkaloids extracted from its rosy periwinkle plant form the basis for some of the most effective cancer treatment drugs, achieving a 90 percent remission rate against childhood leukemia. Yet over the past 40 years, Madagascar has liquidated about half its forests, which contain the overwhelming majority of its biodiversity assets, without realizing offsetting gains in other assets. The country has fallen deeper into poverty, with its GDP per capita falling from $383 (in 1995 dollars) in 1960 to $246 today. In 1997, 16 percent of children died before age five.

What happened? Agricultural productivity stagnated while population tripled. Madagascar's people depend heavily on rice and a few other staple crops. In 1960 average rice productivity was 1.8 tons a hectare—about the same as Indonesia, and much more than the 1 ton a hectare average in Mali. By 2000 productivity had doubled in Mali and more than doubled in Indonesia, but it was almost unchanged in Madagascar. Static productivity—despite a substantial increase in irrigated rice area—reflects in part the implosion of the nation's road network, which fell from 55,000 kilometers in 1960 to 33,000 in 2000. It reflects also a low and declining rate of fertilizer use: only 4 kilograms per hectare, against a Sub-Saharan average of 12 and a developing country average of 96.* Meanwhile, population grew from 5.4 million to 15.5 million.

The combination of an expanding population and stagnant productivity generated pressures for agricultural expansion through forest conversion. Small farmers expanded slash-and-burn cultivation of rice into forest lands officially belonging to the state. The practice is attractive to farmers because of its low labor and input requirements and relatively attractive yields in the first two years. But yields rapidly decline to less than half a ton per hectare after a year or two. Subsequently, the land is used for even lower productivity uses, such as cattle, or it is abandoned. In drier parts of the country, grazing and fuelwood extraction spur forest degradation. So, while 115,000 square kilometers of forest have been lost since 1960, the area under cultivation for staple crops has expanded by only 15,000 square kilometers.

Forest destruction has not only failed to yield new productive land; it has degraded the productivity of existing farmlands and infrastructure. Denuded hillsides are easily eroded: 130,000 hectares of irrigated land have sustained damage or are threatened by sediment. Sediment also clogs hydropower facilities and threatens freshwater and marine ecosystems.

Madagascar hopes to alleviate poverty and reduce pressure on its biodiversity by boosting agricultural productivity. Improving roads in agriculturally productive areas may increase farmer revenues, reduce fertilizer prices, promote intensification, and absorb labor—reducing incentives for farmers to migrate to the forest frontier. In addition, transferring property and management rights of natural resources to local communities is generating incentives for more sustainable use and conservation of these resources. The country also aims to scale up promising sustainable agricultural technologies, such as conservation tillage, that better protect natural resources and that have the capacity to improve profitability. Expansion of the tiny industrial sector may also relieve pressure on the land.

In the medium to long run, Madagascar's unique natural assets may provide the basis for a lucrative tourist industry based on ecotourism and resorts. The country may also be able to benefit from global markets for biodiversity and carbon sequestration services—if these markets develop on a large scale.

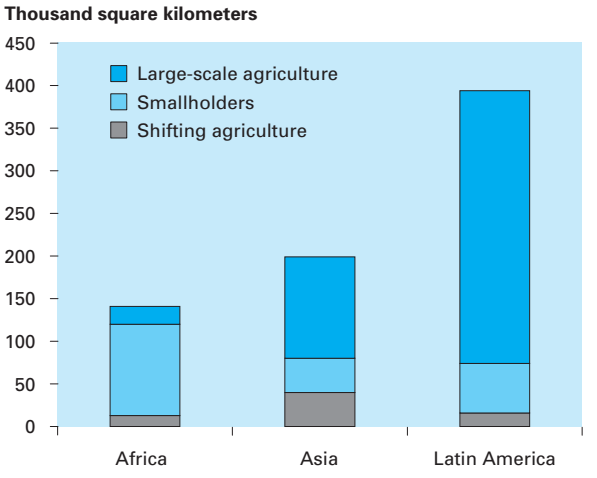
* WRI 2000.
*Source:* World Bank staff. Forest area, cultivated area, and yields from FAOSTAT database; child mortality from Gwatkin (2000).

versions of forest to cassava, upland rice, or rubber agroforest yield negligible returns to land (that is, after the cost of labor is deducted).[27] In Cameroon long and short fallow cultivation of food crops yield present values of, respectively, $288 and $644 per hectare. Intensive cultivation of cocoa offers returns of $785 to $1,236 per hectare, depending on assumptions about cocoa prices; interplanting with fruit boosts returns further.[28] In the Atlantic Forest of Bahia, a highly fragmented long-occupied ecosystem, mean land values are only about $275 a hectare—and remaining forested land is worth (per hectare) 30 percent of equivalent land under agriculture.[29]

Large-scale conversion also yields varying returns. The returns to large-scale monoculture oil palm in Sumatra are estimated at $617 a hectare, not including the $876 that might be realized from sale of timber.[30] But large-scale conversion sometimes yields only modest private and social returns. In the Brazilian Amazon, almost 90 percent of cleared farm property is in extensive pasture or abandoned. Although some ranching may be sustainable, average stocking rates are very low: 40 percent of active pasture has less than 0.5 cattle per hectare. And more than half the converted land is in the 1 percent of properties larger than 2,000 hectares.[31]

Similar variation in actors and profits is found in marine ecosystem degradation. Poor fishers in Southeast Asia practice cyanide fishing to gain a mere $50 a month, threatening reef ecosystems in the process.[32] But highly capitalized and industrial vessels, often subsidized, deplete large fisheries.

**Figure 8.1**
**Current land use in closed canopy forest deforested in 1990–2000**




*Source:* Authors' calculations based on FAO (2000) Table 46-3.

Sometimes ecosystem degradation is an unintended consequence of other activities. Irrigation and flood control, for instance, have altered many ecosystems. And there are growing threats to coastal ecosystems as, worldwide, coastal cities grow, stimulated by booming transocean trade. Already, 20 percent of the world's people live within 25 kilometers of the coast, 39 percent within 100 kilometers.[33] As urban populations grow along the coasts and major rivers, waste streams grow too. The combination of human waste, animal waste, fertilizer runoff, and nitrous oxide emissions generates massive flows of nitrogen into coastal waters. Nitrogen contributes to eutrophication, a major problem in coastal waters, and to the related phenomenon of hypoxia: oxygen-starved "dead zones."[34] It may also be associated with algal blooms, some of which are harmful to people. Concentrated human populations also load coastal waters with sediments, pathogens, and toxic chemicals. And coastal population growth leads to destruction of mangroves and other habitats that nurture biological resources, including the more than 90 percent of the world's marine fish harvest that comes from coastal waters.[35]

### *Who has an interest in maintaining ecosystems?*

While some people gain from ecosystem damage, others suffer, both locally and globally. Some of the local damage affects lives and livelihoods directly and immediately:

- Run-downs of renewable stocks of fish, timber, or wildlife
- Decreased flood buffering and nutrient filtering due to the loss of wetlands
- Increased flooding and sedimentation in small, steep watersheds due to upland land-use change
- Loss of water yield from cloud forests
- Degraded drinking water quality
- Health and other impacts of air pollution from forest and land fires.

These damages can be large. The Indonesian forest fires of 1997–98 caused an estimated $7.9 billion in domestic damages.[36]

Other keenly felt local ecosystem values are difficult to assign a dollar value. Their constituencies may therefore find it hard to counterbalance the more focused interests that derive benefits from ecosystem degradation. For instance, natural habitats may be locally valued for recreational, spiritual, and aesthetic reasons. In a world where incomes are rising and transport costs are dropping, rare ecosystems may have an option value as the basis for a future ecotourism industry. And more speculatively, the genetic, biophysical, and ecological information embodied in biodiversity may be valuable to future agricultural, pharmaceutical, chemical, materials, and information industries.[37] For instance, gene bank collections currently hold 15 percent or less of the genetic diversity of wild relatives of important crop species, including maize, rice, sorghum, millets, and peas.[38] Loss of some of the remaining 85 percent might constrain development of improved varieties of these crops.

### *Biodiversity as a global public good*

The purely global interest in biodiversity focuses on two aspects: diversity itself and the maintenance of global processes. The term *biodiversity* is often used loosely to refer to biological resources. But those who see biodiversity as a truly global public good see a problem akin to Noah's: making sure that a representative selection of the diverse range of genes, organisms, and ecosystems survives the current onslaught of habitat loss, invasions of alien species, overexploitation, pollution, and climate change. The Noah's Ark strategy reflects people's desires, grounded in

ethics and aesthetics as well as economics, to ensure that future generations can benefit from biodiversity. This is not just a concern of the wealthiest nations. A 1992 survey found that world species loss was considered a "very serious" problem by a larger proportion of people in Brazil, Chile, Mexico, and Poland than in Germany, Norway, Switzerland, or the United Kingdom.[39]

Maintaining global biodiversity requires global cooperation. Think about Noah's problem: how do we maintain a representative set of the world's biodiversity? Conservationists have attempted to identify sets of ecosystems, which taken together contain much of the world's biological variety. One such exercise identified a priority set of 233 terrestrial, freshwater, and marine ecoregions based on distinctiveness of species and ecological processes.[40] More than half cross national boundaries, and so would require some kind of coordination for conservation and sustainable use. And as the Convention on International Trade in Endangered Species demonstrates, international cooperation in trade can help to reshape local incentives driving ecosystem degradation.

In addition to considerations of pure diversity, biodiversity is of global interest because the loss of key species or ecosystems could have transborder or global impacts. This is particularly the case for marine ecosystems, where the loss of one species can fray the food web half an ocean away, and for migratory bird species. Large-scale changes in land cover can contribute to regional climate change. There is evidence that a loss of vegetation in West Africa and in the Eastern Amazon can start a self-reinforcing cycle of reduced rainfall and further vegetation die-offs.[41] Deforestation is a major contributor to global climate change. And there is reason to apply the precautionary principle: the global consequences of massive biodiversity loss are unknown.

### *Landscape approaches to biodiversity conservation: Ecosystems meet social systems*

Balancing interests in biodiversity for the public good is going to require a new breed of ecosystem management institutions. For the most part, problems of biodiversity loss cannot be solved at the farmer's plot or fisherman's territory. Solutions need to consider entire ecosystems and social systems for several reasons. First, the incentives driving biodiversity loss must often be addressed at the market level—or the political level that governs access to land and water. Second, actions in one part of an ecosystem can affect a distant part, as when water pollution harms a distant reef. Third, to reduce potential conflict, efficiency is necessary—through incentives that keep agriculture on land with high economic value and low ecological value.

Ecosystem management institutions will take quite different forms, depending on the biodiversity involved and the prevailing systems of tenure and governance. Consider a stylized typology of situations (actual situations will often have aspects of more than one type):

- *Aquatic ecosystems,* marine and freshwater, are far ranging, involve many types of actors, and often spill over national boundaries.
- *Frontier forests* are sparsely settled sites of conflict and exploitation as both corporate and popular interests rush to seize rents and claim property. Biodiversity conservation here is an outgrowth of the more fundamental need to establish governance and rationalize land use. These important issues are discussed at length in chapter 5 and so are not treated here.
- *Commons in transition* are areas, often with fairly high population densities, where management of forests, rangelands, or fisheries has broken down, caused often by government appropriation and mismanagement of commons, in some cases exacerbated by population growth. Sustainable use of biodiversity depends on resolving disputes among communities, and clarifying community and government rights and responsibilities.
- *Fragmented habitats with less-disputed tenure* pose difficult policy questions. They tend to be mosaics of agriculture and natural habitat, where both the private opportunity cost and social benefits of sustainable use are high. They include some of the "hotspot" areas where the risk of losing an entire ecosystem is highest.

To give some flavor of how these stylized types differ, consider the global map of population density in forests (see figure 7 in the roadmap). The great, relatively unbroken, sparsely populated forests of Amazonia, the Congo Basin, and Siberia exemplify frontier forests. The densely populated strands of forest in India and Nepal include commons areas

under transition from government to community administration. And the populated forests of Central America, coastal Brazil, and Madagascar are examples of biodiversity-rich fragmented habitats.

Described here are some of the institutional challenges in addressing the maintenance of these ecosystems. The point emphasized is that to a large extent these are challenges for local management. The global interest is in supporting these local institutions in maintaining assets of global significance and in coordinating action where management issues cross national boundaries.

### *Aquatic ecosystem management*

The need for an ecosystem-wide approach to fisheries has long been obvious, underlined by the recent disastrous crash of some fisheries. The advent of the 200-mile exclusive economic zone places most (but not all) fish stocks under predominantly national control—and that puts nations in a position to regulate these resources for sustainability. (Chapter 7 discusses some of the factors that determine nations' success in doing so.)

But some fisheries require international management. The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) represents an international effort at sustainable ecosystem management—in this case, the 35 million square kilometers of the circumpolar Southern Ocean. The Convention's goal is to manage this area with attention not just to economically exploitable species, such as krill, but to the ecosystem as a whole, encompassing other species of concern, such as penguins and seals.

Similar to the CLRTAP, CCAMLR aims to be an adaptive, learning system. Two working groups, under the supervision of a scientific committee, monitor ecosystem and fishery data. The data help to calibrate ecosystem models and guide decisions by CCAMLR on conservation measures, operationalizing the precautionary principle to ensure that fish stocks do not crash. The Convention faces particular challenges in deterring illegal, unreported, and unregulated capture of Patagonian toothfish (Chilean sea bass), a valuable but very slow-reproducing species. But innovations in monitoring and reporting—including requirements for vessel monitoring systems that permit satellite tracking and implementation of a catch documentation scheme for landings and transshipments of fish—are changing incentives and improving information for management.[42]

Many coastal and marine ecosystems cross national boundaries and demand coordinated transnational action, particularly for enclosed seas and international lakes. The GEF, operating under various mandates to support 45 international waters projects by 2000, has pioneered transboundary diagnostic analysis to identify problems and balance interests across stakeholders. The science-based analysis provides a way of objectively assessing the nature of the problem and engaging stakeholders. It then serves as the basis for agreeing on a Strategic Action Plan. A GEF study found that the analysis and planning, when completed, substantially improved priority setting and consensus forging.[43]

Integrated coastal management is an approach that systematically engages stakeholders in the diagnosis and solution of coastal problems. A recent count found 621 national and subnational examples of integrated coastal management worldwide, with 284 in 99 developing and transition economies.[44] But many of these efforts exist only on paper. Excluding the 110 integrated coastal management efforts in the United States (where the track record is generally longer), only 45 percent are in implementation, and data are lacking on their effectiveness. While integrated coastal management exemplifies the institutional approach to collective action problems championed by this Report, it has not yet fully demonstrated its potential.

Sixty percent of the earth's freshwater resources are found in international river basins, within the borders of more than one state.[45] Forty percent of the world's people live in those shared basins, all with expectations of using the rivers' resources. Historically, competing demands for shared waters have led to tensions and conflict. As populations grow and economies develop, more pressure will be brought to bear on these shared resources. To promote peace, to sustain river basin ecosystems, and to meet the development needs of all those who depend upon shared water resources, it will become imperative that countries cooperatively sustain, manage, and develop international river basins. The Nile Basin Initiative responds to this challenge (box 8.4).

### *Commons in transition*

In South Asia, much of Africa, and parts of Southeast Asia there are regions where people have used forests and woodlands for generations. Historically, some of these common property resources were well managed

**Box 8.4**
**The Nile Basin Initiative**

An extraordinary example of cooperation in the management of international river basins is evolving in the Nile River Basin. The Nile, at almost 7,000 kilometers, is the world's longest river. The basin covers 3 million square kilometers and is shared by 10 countries: Burundi, the Democratic Republic of Congo, the Arab Republic of Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. Tensions, some ancient, arise because all riparians rely to a greater or lesser extent on the waters of the Nile for their basic needs and economic growth. For some, the waters of the Nile are perceived as central to their survival.

The countries of the basin are characterized by extreme poverty, widespread conflict, and increasing water scarcity in the face of growing water demands. This instability compounds the challenges of economic growth in the region, as does a growing scarcity of water relative to the basin's burgeoning population. About 150 million people live in the basin today, with growing water demand per capita. More than 300 million people are projected to be living in the basin in 25 years. The pressures on scarce water resources will be very great.

The countries of the Nile have made a conscious decision to use the river as a force to unify and integrate—rather than divide and fragment—the region, committing themselves to cooperation. Together they have launched the Nile Basin Initiative, led by a Council of Ministers of Water Affairs of the Nile Basin, with the support of a Technical Advisory Committee, and a Secretariat in Entebbe, Uganda. The initiative is a regional partnership within which the countries of the Nile Basin have united in common pursuit of the sustainable development and management of Nile waters. Its Strategic Action Program is guided by a shared vision "to achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources." The program includes basinwide projects to lay the foundation for joint action, and two subbasin programs of cooperative investments that will promote poverty alleviation, growth, and better environmental management. The initiative enjoys the strong support of many donor partners through an International Consortium for Cooperation on the Nile, chaired by the World Bank.

The Nile waters embody both potential for conflict and potential for mutual gain. Unilateral water development strategies in the basin could lead to serious degradation of the river system and greatly increase tensions among riparians. But cooperative development and management of Nile waters in sustainable ways could increase total river flows and economic benefits, generating opportunities for "win-win" gains that can be shared among the riparians. The Initiative provides an institutional framework to promote this cooperation, built on strong riparian ownership and shared purpose and supported by the international community. Cooperative water resources management might also serve as a catalyst for greater regional integration beyond the river, with benefits far exceeding those from the river itself.

*Source:* World Bank staff.

by community institutions. Elsewhere the resources were so abundant that there was no need for elaborate management. In both cases, many of these woodlands were appropriated by colonial governments, often eager for timber revenues. The problem was that these governments and their independent successors often lacked the ability to manage and protect these resources—and the interest in involving the communities that used them. As population and economic pressures increased, these woodlands have become degraded through conversion and overexploitation.

Since 1985 many countries have begun to transfer control of woodlands back to local communities. Bolivia, Colombia, and Peru transferred almost 50 million hectares to community ownership; Bolivia, Brazil, India, and Peru set up community management over 111.1 million hectares. Indonesia, Nepal, Sudan, Tanzania, and a number of other countries have undertaken similar programs.[46]

Projects in these countries seek to foster community institutions for forest management, as well as formally transfer authority. Doing so often requires changing the national policies and laws for forests and land tenure—and changing the incentives and organizational culture of the national forestry or land management authority. It also requires negotiating rights among traditional users of common property resources—and building social capital and management capacity in local communities. These are formidable challenges, but a decade of effort has yielded some encouraging results—as well as cautionary lessons. Projects in India and Nepal show that communities can realize greater income and environmental gains through management and recuperation of highly degraded forest areas. But there has sometimes been less willingness of government to relinquish areas that still contain valuable timber resources.[47]

### *Fragmented habitats with less-disputed tenure*

The tradeoff between biodiversity goals and private profits is most problematic in more extensively modified areas where most of the original habitat has been lost. These lands, attractive to settlement, retain less-disturbed natural habitat patches within mosaics of agricultural land. One study identified a

set of such areas, the hotspots that have lost more than 70 percent of their original area and now hold about one-third of the world's terrestrial biodiversity on just 1.4 percent of the Earth's surface.[48]

Fragmentation raises the risk of extinction. Smaller fragments support fewer species. Species caught in shrinking fragments may vanish locally; if they are unlucky enough to be restricted to just a few fragments, they risk extinction. It takes time, though, for species to vanish in a newly isolated fragment, as their populations dwindle slowly. In a 10 square kilometers fragment, half the threatened species—those unsupportable by the smaller fragment—are lost in 50 years;[49] in a 1 square kilometer fragment the half life is just 10 years.[50] So over the coming decades there is the risk of an avalanche of extinctions—and the consequent loss of entire ecosystems—if habitat loss and fragmentation continue. But there is also the possibility of reversing the decline if action is swift enough now.

Because these areas have been settled longer, parts of them may exhibit reasonably well-defined land tenure for individuals or groups—though rarely without some degree of dispute. And tenure generally carries with it some measure of legal or traditional rights to modify land cover. So the problem of establishing governance is less pressing than in frontier forests (though rarely absent), and attention focuses on reconciling the interests of landholders with those of the wider community.

The proximity of people and habitats increases the value of environmental services, such as flood prevention and recreation. But favorable agroclimatic conditions and dense populations motivate landholders to drain wetlands, to appropriate stream flows, to "mine" forests, and to expand their towns, croplands, and pastures. These areas thus have high conservation values for the local and global community—and often high exploitation values for the landholder. How can these values be reconciled?

The general approach is to use markets, regulations, or inducements to change the landholder's incentives. It helps to distinguish between incentives that are self-enforcing and those that require external monitoring and enforcement.

Much project-oriented work in promoting biodiversity (apart from establishing protected areas) has been aimed at setting up self-enforcing incentives through new technologies or through new markets. The dream is that a one-time intervention would be sufficient to create a sustainable source of value in biodiversity, one that the landholder would then be motivated to maintain rather than mine. An elegant pilot project in Peru illustrates the principle. There, villagers will "ranch" valuable poison dart frogs in the forest, using a technique that hatches and harvests in a sustainable manner more juveniles than would normally grow. Only juveniles will be exported; since they are impossible to catch in the wild, the scheme will not induce poaching if properly enforced. The frogs fetch high prices, so there is a strong incentive to keep the forest in place.

But there is a growing consensus that this kind of fully self-reinforcing approach, while locally important and worth pursuing where possible, may have limited scope. Few wild biological resources are extremely profitable, resistant to domestication, and more attractive for a landowner to maintain than to liquidate. Large trees, for instance, grow more slowly than money in the bank, so they are always tempting to liquidate in the absence of regulation or strongly felt nonmarket values. Ecotourism today rarely confers substantial per hectare returns, though there are some examples of success (often partially subsidized by donors) in community wildlife management in Africa.[51] Integrated conservation-development projects, premised on the idea that improved local livelihoods would reduce pressure on habitats, have also been disappointing. In some cases local agents were not responsible for habitat degradation; in others unconditional provision of additional income did nothing to diminish the attractiveness of overexploiting natural resources.

A more promising approach to self-reinforcing incentives seeks to shift farmers to more biodiversity-friendly forms of land management.[52] This includes promoting agroforestry systems that mimic and complement the biodiversity and hydrological functions of the original ecosystem while providing more income and employment than annual crops. In Sumatra, smallholder rubber agroforests improved planting stock may be able to maintain half the species richness and carbon levels of primary forest, while offering profits and employment generation superior to that of biodiversity-poor oil palm plantations.[53] Such systems may help to restore biodiversity in degraded ecosystems dominated by agricultural production, to reduce habitat damage downstream from intensive agricultural areas, and to enhance the con-

servation effectiveness in protected areas by enhancing the habitat quality of surrounding land uses.

But those introducing ecofriendly farming approaches walk a knife-edge. Not profitable enough, and the approach will be shunned. Too profitable, and it could displace the habitats it is supposed to save. So agroforests and similar approaches can complement but not substitute for the maintenance of some areas of natural habitat, and may not always be self-enforcing.

### *Equity and efficiency in blending development and conservation*

Disillusionment with the self-enforcing approach has prompted interest in an alternative that compensates landholders for agreeing to externally verified restrictions on land use.[54] Payments may be ongoing, or where legal institutions are strong, landholders may agree to permanent conservation easements on their property in return for a one-time payment. Payments may be directly financed by the state on behalf of the beneficiaries of environmental services. Or the state may create a market for these services by imposing regulatory requirements on environmental service users.

A well-known example is the U.S. Conservation Reserve Program, which spends about $1.5 billion a year in incentives for landholders to remove environmentally sensitive land from production and establish vegetation that prevents erosion. Funding is based on a scoring system that considers a range of environmental benefits as well as the farmer's asking price, resulting in a cost-effective award system. Europe spends a comparable amount for conservation set-asides.[55]

In the developing world, Latin American countries are leading the way. Costa Rica's Payment for Environmental Services Program (box 8.5) aggregates financing for forest conservation from a variety of dispersed beneficiaries:

- Urban water users (who pay for sediment reduction).
- Run-of-river hydropower facilities (which care about regulation of water flow).
- Domestic taxpayers (concerned with biodiversity and scenic beauty, for their own enjoyment and as a source of tourism and bioprospecting revenue).
- Foreigners (seeking carbon sequestration credits to comply with voluntary or regulatory limits on net $CO_2$ emissions).

Funds are then used to purchase five-year renewable conservation easements on forested property.

Brazilian states have recently introduced two extremely innovative financing mechanisms. One, the ICMS Ecológico (box 8.6), modifies state revenue-sharing rules to reward municipios (districts) that create public or private protected areas, or protect watersheds. The other (box 8.7) introduces tradability of a long-standing obligation of landholders to maintain a set proportion of each property as a forest reserve. With tradability, farms that are out of compliance can potentially pay others to maintain and expand high-quality forest of biodiversity value, rather than uproot profitable, employment-generating crops in a vain and expensive attempt to recreate a vanished forest. This reduces compliance costs by creating a market for conservation services. Paraná state has recently used tradability as a means of securing stakeholder support for a new law that seeks to secure universal enforcement of the forest reserve obligation.

These examples point the way toward ecosystem management institutions with three important features aimed at balancing interests and forging long-term commitments. First, they would foster a participatory formulation of a vision and specific goals for regional development and landscape management. Environmental goals might well include maintenance of representative ecosystems over areas large enough to ensure their long-term viability. Second, they would allow for flexibility in achieving those goals, reducing the scope for conflict among stakeholders and reducing social and private costs of outcomes that are valued but hard to measure in financial terms. Third, they would set up incentives for landholders to realize the regional vision.

International contributions of funds to such domestic landscape management institutions might be one way to meet both international and domestic goals, while keeping land ownership and management firmly in domestic hands. The domestic institution would assess local goals and priorities, set up transparent rules for providing and distributing incentives, establish compliance and enforcement mechanisms, and receive domestic and international financing, both public and private. It might well be integrated with regional development authorities and use funding to address poverty alleviation needs that are only indirectly tied to land use but are per-

**Box 8.5**

**Costa Rica's program of payment for environmental services**

Costa Rica has pioneered a program that allows those who benefit from the environmental services of forests to compensate those who bear the burden of maintaining those forests. The Payments for Environmental Services Program is an outgrowth of a landmark 1996 Forestry Law, which recognizes four environmental services provided by forest ecosystems: mitigation of GHG emissions; hydrological services, including water for human consumption, irrigation, and energy production; biodiversity conservation; and scenic beauty for recreation and ecotourism. Under the program, users of these services finance a national forestry fund (FONAFIFO), which in turn contracts with private landholders for forest conservation and application of sustainable management practices.

The program arose from a growing awareness of forests' importance against a backdrop of rapid deforestation. In 1950 forests covered approximately half of Costa Rica. But in the 1970s and 1980s, the country's deforestation rate was among the highest in the world. Appreciation of the importance of Costa Rica's biodiversity—both as an element of the national patrimony and as a source of revenue through ecotourism—prompted the creation of an extensive national park system. Even so, much of the nation's forest remained in private hands. And from a landholder's viewpoint, extraction of all salable timber and conversion to pasture was more profitable than sustainable forestry, and certainly more profitable than strict forest conservation. By 1995 forest cover had fallen to just one-quarter of Costa Rica's territory. But from the early 1990s there had been increasing attention by NGOs and government agencies to the environmental services of forests, catalyzed in part by a World Bank study that tried for the first time to place economic values on forest environmental services. These discussions culminated in the new forestry law.

The national forestry fund contracts with individuals (for up to 300 hectares of primary and mature secondary forest), with indigenous reserves, and with NGO groups representing smallholders. There are three types of contracts: for conservation of existing forests, for sustainable forest management, and for reforestation. In all cases, participants must present a forest management plan, certified by a licensed forester, that describes the biophysical condition of the land, sets up a monitoring schedule, and specifies actions for the prevention of forest fires, illegal hunting, and illegal harvesting. The landholders cede rights to environmental services (such as sequestered carbon) to FONAFIFO. Payments differ by contract type. Forest conservation contracts, which constitute 85 percent of the contracted area, pay $42 per hectare a year for five years against the completion of specified tasks. By the end of 2001, 4,461 contracts covered 283,384 hectares, with 14 percent of the area belonging to indigenous groups.

The fund finances the program in part through the sale of these services. Hydropower producers, including both small private facilities and the state-owned Compañía Nacional de Fuerza y Luz, are interested in purchasing environmental services such as stream-flow regulation, sediment retention, and erosion control. These private and public sector companies have signed multiyear contracts totaling more than $5.5 million. International sales of carbon offsets (carbon sequestration services) have netted $2 million. The GEF, through the World Bank, recently provided $5 million to support forestry conservation contracts in priority areas of the Mesoamerican Biological Corridor as well as an additional $3 million to strengthen program implementation. This is supplemented by a $32 million World Bank loan to support the program while long-term financing mechanisms are developed and institutionalized. So far, the bulk of the $57 million expended has come from a nationwide fuel tax.

As a pioneering effort, the program faces a variety of challenges—among them, reducing the costs of monitoring and enforcing thousands of small contracts, optimizing the Program's impact on environmental quality, and securing long-term sustainable sources of finance.

*Source:* Ortiz Malavasi and Kellenberg, background note for *WDR 2003*.

ceived as being part of a comprehensive vision of sustainable local development. Having such an institution in place as a precondition for international conservation finance would allay international fears that the promise of funding would perversely induce greater habitat destruction. It would also allay domestic fears of foreign control of land and threats to sovereignty.

## Mitigating and adapting to risks of climate change

People are changing the planet's climate. Burning fossil fuels—and to a lesser but important extent, deforestation and other land use practices—releases $CO_2$ and other greenhouse gases (GHGs). Accumulating more rapidly in the atmosphere than can be removed by natural sinks, these gases trap heat, changing climate in complex ways, with widespread impacts. This is quintessentially a global problem because GHGs mix rapidly in the atmosphere and have the same impact on climate change regardless of where they are emitted. And it is a long-term problem because the great inertia in social, economic, and physical systems means that it would take decades to moderate the rate of change substantially.

Because of its characteristics, climate change has been a particularly difficult problem to solve. It has been difficult for society to pick up signals—to understand the causes, magnitude, and consequences of climate change. Atmospheric $CO_2$ has been increas-

**Box 8.6**
**Municipal incentives for conservation**

A major source of state finance in Brazil is a value added tax, the ICMS. One-quarter of the tax is rebated by states to municipalities. Of this payment, three-quarters must be proportional to the municipality's contribution; the rest may be distributed according to criteria set by the state. Four states—Paraná, São Paulo, Minas Gerais, and Rondônia—now use the area under protection as one criterion for redistribution.

The ICMS Ecológico is a unique Brazilian mechanism that uses state-to-municipality (including rural districts) transfers to reward the creation and maintenance of protected areas for biodiversity conservation and watershed protection. The intent is to counteract local perceptions that maintenance of protected areas reduces municipal revenue. This provides an incentive for local authorities and communities to support the establishment of protected areas rather than permit, say, the expansion of extensive cattle ranching. But the revenue transfers are untied and need not be devoted to park management.

The proportion devoted to protected area incentives varies from 0.5 percent in Minas Gerais to 5 percent in Paraná and Rondônia. In Minas Gerais much of the redistributive portion of the ICMS is used to support social objectives other than environment.

While the ICMS Ecológico represents only a small proportion of total ICMS disbursements, it constitutes a relatively large incentive by the standards of conservation programs. Annual budgets have been about R$50 million in Paraná and R$15 million in Minas Gerais. (Until 1999, the Brazilian real and U.S. dollar were roughly equivalent.)

Since the programs were adopted, about 1 million hectares have been placed under environmental zoning restrictions in Paraná, and about 800,000 in Minas Gerais. Field interviews suggest that municipal authorities deploy local incentives to induce landholders to undertake these restrictions, in order to attract state funding. The ICMS Ecológico is thus an interesting mechanism because it affects landholder incentives without incurring the large transactions costs associated with payments directly to landholders. Its effectiveness, however, depends on the ability of the state to monitor and enforce landholders' compliance with conservation commitments.

*Source:* May and others (forthcoming). See also Bernardes (1999); Grieg-Gran (2000).

**Box 8.7**
**Tradable forest obligations efficiently meeting conservation goals**

The Brazilian state of Paraná has created a market for conservation by allowing trade in landholder obligations to maintain forests. A long-standing Brazilian law has required that property owners maintain 20 percent of each property under native vegetation (50 percent to 80 percent in the Amazon region). But noncompliance was common.

Paraná's new law allows landowners to satisfy their forest reserve requirements off site, on areas of greater ecological significance but lower opportunity cost. "Trading" of forest reserve is allowed only within biome–river basin combinations in order to ensure full representation of the state's biodiversity. As an incentive for compliance, landholders must prove that they are registered with SISLEG to carry out any legal transaction related to their land, such as sales.

A preliminary analysis of a hypothetical similar program for the nearby state of Minas Gerais illustrates how efficiency-enhancing programs such as this might increase biodiversity conservation and economic output. In a scenario in which forest reserve requirements are enforced property-by-property, landholders with less than 20 percent forest cover achieve compliance by abandoning their land to spontaneous regrowth. Because this land is heavily worked and has sparse seed sources, this regrowth is likely to be of low quality, with little real environmental benefit. The private costs of compliance are estimated at about R$1.5 billion. In the trading scenarios, landholders may achieve compliance in part by purchasing forest protection or regeneration from others who have more than 20 percent forest cover. Because of the proximity of forest remnants, regeneration from this source is likely to be more vigorous and of substantially greater ecological value. When landholders are free to trade within the same biome, compliance costs drop by almost three-quarters, while the proportion of higher-ecological-quality forest reserve increases to 72 percent.

*Source:* Chomitz, Thomas, and Salazar Brandão (forthcoming).

ing since 1750. Svante Arrhenius surmised in 1896 that this might affect global climate, but emerging consensus on aspects of the problem has been achieved only a century later with the IPCC (described earlier). Dispersion of interests in mitigating climate change has been a barrier to achieving agreement on actions. Many of the people most vulnerable to climate change are poor, live in remote regions—or have not even been born. Even the vulnerable wealthy—owners of oceanfront property, for instance—may not yet rank climate change among their greatest current concerns. The voice of these numerous but diffuse interests is weaker than that of industries and consumers, especially wealthy ones, that are

heavily reliant on fossil fuels and would bear the burden of control costs. Finally, climate change is an extreme example of the commitment problem described in chapter 3. Mitigation of climate change will require a concerted, decades-long effort.

With these barriers in mind this section starts by reviewing the consequences and sources of climate change. Using this information, it assesses institutional aspects of undertaking the long-run mitigation of climate change. Then, it examines issues related to adapting to the climate change that past actions have already made inevitable—and that lack of progress in mitigation will exacerbate.

### *Consequences and causes of climate change*

Climate change is already here.[56] Over the past century, mean global surface temperature has increased by 0.4° to 0.8° Celsius (C). According to the IPCC, GHGs released by human action are likely to have been responsible for most of the warming of the past 50 years. Other observed changes are consistent with this warming. Sea levels rose 10 to 20 centimeters over the past century. Over the past 50 years, the summer extent of arctic sea-ice has shrunk by 10 percent or more, and its thickness by 40 percent. Outside the polar regions, glaciers are retreating, affecting mountain ecosystems and water flows. Droughts have become more frequent and intense in Asia and Africa. Many of the world's coral reefs have been damaged by bleaching (see note 21), associated with higher sea temperatures. Animals and plants have shifted their geographic ranges and behavior. Extreme weather events may have increased.

Unchecked, these impacts are predicted to intensify, posing risks of varying kinds for different countries. Impacts will fall heavily on many developing countries, including those that have not contributed to climate change. They are physically vulnerable. Climate-sensitive agriculture bulks large in their economies. And they have less institutional capacity to adapt to change.

Low-lying islands and coastal areas everywhere will be exposed to flooding and storm damage. Bangladesh, for instance, may be severely hit. A recent study predicts that by 2030 an additional 14 percent of the country would become extremely vulnerable to floods caused by increased rainfall.[57] A 10-centimeter increase in sea level would permanently inundate 2 percent of the country, with the additional effect of making floods more severe and longer lasting. Saltwater intrusions, and more severe dry seasons, will reduce fresh water availability in coastal areas. As coastal populations swell worldwide, a 40-centimeter rise in the sea level would increase the number of coastal dwellers at risk of annual flooding by 75 to 206 million—90 percent of them in Africa and Asia.[58] The starkest local impacts are faced by the low islands of the Pacific, some of which could lose their freshwater and be largely inundated during storm surges if sea levels rise.

Climate change could damage developing-country agriculture. Even taking into account crop substitution possibilities, one study finds that a 2° C temperature increase decreases the value of Indian agricultural land by 36 percent.[59] Arid and semi-arid areas in Africa and Asia will probably face higher temperatures. Feedback between vegetation loss and reduced rainfall could result in faster desertification.[60]

Impacts on industrial countries are thought to be mixed, but may be generally negative.[61] Agricultural productivity will likely improve, in the medium term, in some northern areas. But southern Europe will likely suffer drier summers; much of Europe could experience river flooding. The Atlantic coast of the United States will be vulnerable to rising sea levels, and Australia will likely be more subject to drought.

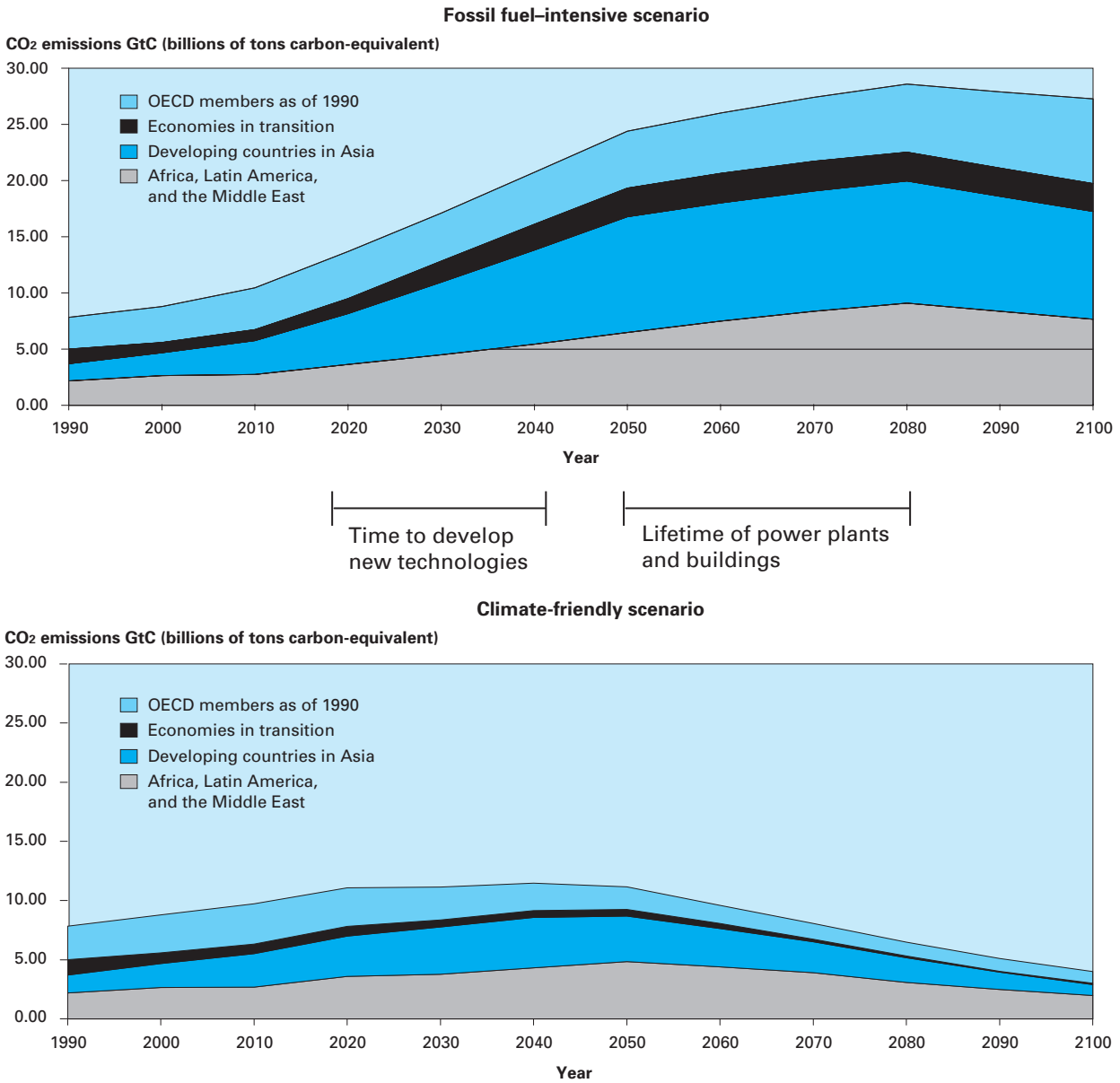
Current understanding also depicts the global climate as a finely balanced mechanism that goes awry when stressed, with prehistoric instances of 10° C global temperature changes occurring within the span of a decade.[62] There is a risk of catastrophic consequences of climate change that could be irreversibly set in motion during this century. There could, for instance, be an abrupt failure of the great ocean "conveyor belt" currents that warm the North Atlantic and mix deep with surface waters. Biodiversity losses could be massive as habitat fragmentation makes it impossible for plants and animals to migrate in response to rapidly changing temperatures. The risks are difficult to evaluate, but they affect industrial as well as developing countries and are credible enough to demand attention. At the very least they put a premium, or option value, on maintaining lower levels of atmospheric GHGs while the world more carefully examines the consequences and develops options for mitigation.

What drives climate change? GHGs have built up in the atmosphere as a consequence of 250 years of emissions from burning fossil fuel, deforestation, and other sources. Currently, about 40 percent of the

human-induced heating effect[63] is from increased atmospheric concentrations of methane (from landfills, rice paddies, and cows), nitrous oxide (from industry and agriculture), and halocarbons such as CFCs. The remaining 60 percent is $CO_2$. Of the approximately 28.2 billion tons of annual $CO_2$ emissions, 23.1 billion are from energy and other industrial sources. This component is closely linked to income, across countries, though there is considerable variation in emissions per dollar of GDP and emissions per capita among the wealthier countries. The remaining 5.1 billion tons come from tropical deforestation.

A look at two scenarios[64] for future $CO_2$ emissions will help provide background for understanding the challenge of mitigating climate change (figure 8.2).

**Figure 8.2**
**Fossil fuel–intensive and climate-friendly scenarios 1990–2100**




Fossil scenario: +3° to 6.9° C temperature increase by 2100. Climate-friendly scenario: +1.2° to 3.3° C temperature increase by 2100.
*Source:* Emissions scenarios A1FI and B1 from Nakicenovic and Swart (2000); temperature predictions from Stott and Kettleborough (2002).

Both scenarios start in 1990, with emissions per capita in OECD countries six times the level in Asia (excluding Japan), and with total emissions about equally divided between the developing and developed world. Both scenarios posit rapid economic growth—and substantial convergence of per capita GDP between developed and developing countries. The top panel scenario is not a static extrapolation of current technologies. It already incorporates rapid technological progress, with a 75 percent reduction in energy use per dollar of GDP, and increased use of renewables (up to 17 percent from 5 percent in 1999).

Nonetheless, emissions increase radically over the century, and industrial country emissions in 2100 are far above world emissions in 1990. By 2100 the implied mean increase in global temperature is 3.0° to 6.9° C.[65] The bottom panel scenario posits more vigorous technological change, with a much less energy-intensive economy and a 52 percent share of renewable energy. This holds the temperature increase to the range 1.2° to 3.3° C.[66] In both scenarios, OECD emissions per capita are still twice the level of the developing countries at the end of the century.

These scenarios are illustrative rather than predictive. But they convey three points that are essential to understanding the problems of balancing interests and executing agreements. First, emissions per capita in industrial countries are much higher than in developing countries and are likely to remain higher for some time. In response to this imbalance—richer countries imposing higher per capita externalities—the U.N. Framework Commission on Climate Change (UNFCCC) established differentiated responsibilities for developed countries, requiring them to take the lead in addressing climate change and providing needed technology to the developing world. Second, developing countries will nonetheless emit substantially more than developed countries in the future and therefore must be involved in implementation. Third, pursuing the more climate-friendly scenario requires starting now. Much capital stock—such as power plants and buildings—has a working life of 50 years or more. And many of the renewable and low-carbon energy technologies required for the favorable scenario will require 10–20 years of research and development to bring to market. To have high-efficiency, low-carbon capital in place in the latter half of this century, the process of research, development, and deployment of human-made capital—incorporating greater energy efficiency and increased use of renewables—has to begin now.

In sum, those whose actions cause climate change, and those who bear its risks, form two diverse and only partially overlapping sets of actors. This diversity raises issues of equity and efficiency in seeking options for climate change mitigation—and financing for both mitigation and adaptation.

### *Mitigating climate change*

Concerned about climatic risks, most of the world's nations agreed in 1992 to the UNFCCC. The convention's objective is defined as the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." But the Convention itself did not quantify this level or specify how to achieve it.

As a first step the Kyoto Protocol to the UNFCCC was negotiated in 1997. This agreement would require industrial nations and economies in transition—the Annex B countries—to accept specified limits on emissions of GHGs for 2008–12. The Protocol would decrease compliance costs by allowing Annex B countries to trade their emissions allowances. It would also allow these countries to purchase emissions reductions from developing countries, the reductions being reckoned against assumed "business as usual" levels, since the developing countries' emissions were not capped. The subsequent Marrakech Accords of 2001 allowed for developing countries to generate emissions reductions from forestry projects in only a limited way. At this writing, the Kyoto Protocol has not entered into force.

It is important to recognize that the Protocol's commitments for 2008–12, even if observed by all major emitters, would be only a first step toward the UNFCCC goal. Keeping this in mind, this chapter outlines some strategic considerations in pursuing that long-run goal, a cornerstone of global sustainability.

If the world is to stabilize atmospheric concentrations and provide good living standards to all its citizens, it must switch in the long run to energy technologies (such as wind, solar power, and hydrogen, among others) that emit near-zero net amounts of $CO_2$. Simple arithmetic shows why. The world's population is now expected to stabilize at about 9 bil-

lion around mid-century. Suppose that people then aspire to the current lifestyle of a prosperous country. Among the prosperous countries, Norway has one of the lowest ratios of $CO_2$ emissions per capita from energy, owing in part to ample use of hydropower. Yet if the global population of 2050 emitted $CO_2$ on average at this rate, the total would be about 2.5 times current global emissions,[67] which would greatly exceed the planetary absorptive capacity.

Between now and the time the world switches entirely to near-zero-emissions technologies, GHGs will accumulate in the atmosphere. The amount of damage, and the risk of catastrophic changes, will be related to the cumulative amount. To reduce the damage, the world needs to accelerate the shift to lower-emissions energy technologies, increase the efficiency of energy use, and reduce the emissions of GHGs.

Although these actions provide some immediate side benefits in addition to their cumulative effect on reducing climate damages, they involve costs. Because emissions reductions represent a global public good, burden sharing is inevitably contentious. To facilitate global coordination in this effort, a strategy has to reduce the overall cost of mitigating emissions and seek to align local and global interests as far as possible. It also has to avoid free-rider problems. This requires further institutional innovation at both national and global levels.

An adaptive strategy for mitigating climate change provides incentives for taking action now to reduce GHG emissions over three time horizons: near term (5–10 years), medium term (10–20 years), and long term (20–50 years). The global climate change strategy has to be adaptive because climate change mitigation will take most of this century to accomplish. Economic, environmental, and political conditions—and our understanding of climate change—will certainly change markedly over this period. Some actions need to be undertaken now—the impact of those actions will play out over these three time horizons:

- Vigorously pursue current options to cheaply abate GHG emissions, thus reducing the possibility of triggering catastrophic climate changes and buying time for longer-term, more fundamental actions to take hold.
- Set up incentives to ensure that the next generation of long-lived capital stock—transport, generators, and buildings—is energy efficient, to encourage agricultural intensification and maintenance of carbon stocks in forests, and to shift urban structures toward lower energy use.
- Start now on research and development to ensure that zero-emission energy technologies can be developed and widely deployed by mid-century.
- Building on current efforts, create adaptive international institutions for fostering cooperation and burden sharing.

### *Act now to reduce today's emissions*

Although non-OECD countries use only about 20 percent as much energy per capita as OECD countries, they use 3.8 times as much energy per dollar of GDP.[68] This disparity suggests looking for ways that developing and transition countries can increase efficiency and reduce fuel costs—with reduced GHG emissions as a welcome side-benefit. Why are these apparent "win-win" opportunities so elusive? Two types of institutional failures get in the way. First, distortions in energy policy may disadvantage society at large, but benefit special interests. Second, firms and households neglect profitable ways of saving energy because it is simply too much trouble to pursue them. Fortunately, there are institutional solutions to both of these problems—though neither is easy to solve.

Many energy-rich countries subsidize energy consumers or producers, resulting in inefficient fuel use, an inappropriate fuel mix, and needless $CO_2$ emissions. Box 7.6 discussed Iran, which spends 18 percent of its GDP on petroleum product subsidies. Coal subsidies in OECD countries were $8 billion in 1997.[69]

Dismantling subsidies to energy—or to inefficient energy-using industries—is no easy task, for reasons that this report has discussed at length. But it is possible. China reduced $CO_2$ emissions by 7.3 percent over 1996–2000, largely through industrial restructuring and fuel improvements, while increasing its GDP by 36 percent.[70] These reductions were accompanied by a 32 percent reduction in particulates, which have severe health effects and contribute to global warming.[71]

In both industrial and developing countries households and firms pass up energy-saving investments with extraordinarily high financial rates of return—on paper. Investments such as efficient electric mo-

tors, compact fluorescent lights, improved boilers, and insulation can often pay for themselves in a year or two, in the process yielding reductions of both GHGs and local air pollutants. But it takes effort and attention to discover these opportunities, which may appear burdensome and risky to pursue. Consumers may legitimately wonder if an expensive light bulb is really going to last long enough to produce the advertised savings, or if the spectrum of the illumination will be unpleasant. They may not know or much care that some appliances draw a couple of watts of stand-by power, though on a national scale those watts add up to entire generating stations. Corporate executives or government facility managers may not have the information or incentive to find opportunities for reducing heating bills.

New sets of institutions are making it easier for consumers, business, and governments to take advantage of energy efficiency opportunities. These include government initiatives to set standards and disseminate information about efficiency. These initiatives, pioneered in industrial countries, are now being extended to developing and transition economies. Thailand introduced a $189 million demand-side management program in 1993.[72] The program first targeted lighting, which accounts for 20 percent of Thai electricity consumption. The program persuaded Thai manufacturers of fluorescent lights to switch to a new design that consumed 10 percent less energy. The program eased consumer acceptance through a combination of advertising and imposition of standards for light quality and durability. Within a year the new lighting commanded 100 percent of the market. Estimated benefit-cost ratios were 54.6 for consumers and 13.8 for society as a whole, taking account of the program costs.

There appear to be many opportunities for developing countries to reduce GHG emissions at a cost just high enough to be a local deterrent, but quite low for the world. The capture of methane from landfills is an example with global applicability (box 8.8). Examples such as these motivate the "carbon market," which mobilizes funds from the industrial world to tip the balance toward clean energy in the developing and transition economies.

Agricultural intensification, combined with protection of forests from wasteful destruction, has the potential to dramatically reduce $CO_2$ emissions while

**Box 8.8**
**The Prototype Carbon Fund and the carbon market**

The Prototype Carbon Fund is a pilot effort to "show how project-based greenhouse gas emissions reduction transactions can promote and contribute to sustainable development and lower the cost of compliance with the Kyoto Protocol." The Protocol, if it comes into force, sets up opportunities for developing countries and economies in transition to adopt cleaner technologies and sell the resulting reductions in GHG emissions to industrial countries that have committed to limits on their own net emissions. (Indeed such a market may come into being even if the Kyoto Protocol fails, arising from national-level policies and voluntary markets for emission reductions.) The carbon market offers tremendous potential. It could reduce the cost to industrial countries of achieving any agreed goal for emissions reductions. It could stimulate the development of renewable energy technologies. And it could provide technology, environmental benefits, and export revenues to the developing and transition world.

Achieving this potential, however, requires resolving a host of technical and institutional problems. Can emission reductions be produced at reasonable cost? How do you credibly measure them? How do you contract for them? Do they really contribute to sustainable development? Answering these questions is important not only for the implementation of carbon markets, but for fostering consensus on their feasibility.

The Prototype Carbon Fund is a learning-by-doing enterprise to help answer these questions. With $145 million contributed by six national governments and 17 private firms, it seeks to purchase emission reductions from 25–30 projects. Its first project finances methane capture and electricity generation at a municipal landfill in Latvia. Without this financing the city of Liepaja would not have found it attractive to capture the methane that landfills emit. The capital costs are high relative to the value of electricity; the economic rate of return would have been only 2.6 percent. A combination of carbon and grant financing for the initial investment boosts the city's return to 22 percent. It will also result in an estimated reduction of 681,000 tons ($CO_2$ equivalent) of GHG emission, because methane is a powerful heat-trapping gas; using it for electricity not only directly reduces emissions, but also reduces combustion of fossil fuels. The project also provides the city with a landfill built to higher environmental standards.

In undertaking this transaction, the Prototype Carbon Fund pioneered the development of institutional tools for contracting, monitoring, and verifying emission reductions. This information has been widely disseminated as a global public good, reducing transactions costs for future methane-capture projects.

*Source:* World Bank (2002h).

reducing rural poverty, protecting biodiversity, and providing local environmental services. As mentioned earlier, land-use change contributes 5.1 billion tons per year of $CO_2$ to the atmosphere, plus or minus 50 percent—that is, 10 percent to 30 percent of total human emissions.[73] Most of the land-use emissions result from the conversion of tropical forests. A substantial portion of this conversion yields pasture or croplands with modest returns. The agricultural intensification strategy described in chapter 5 keeps these forests in place, for future sustainable use, and promotes labor-intensive cropping in more suitable lands. Improved soils and denser crops also serve to absorb $CO_2$, which increases the land's productivity and resilience. Timber plantations, agroforestry, and biomass plantations could add substantially to sequestration while improving rural livelihoods.

Incentives for forest conservation and soil carbon present implementation problems but offer a vast payoff. Throughout the tropical world farmers may burn a hectare of rainforest to get a one-off gain of a few hundred dollars—while releasing hundreds of tons of $CO_2$ and destroying priceless biodiversity. Each year, according to FAO data, deforestation claims 3.8 million hectares of tropical forest with biomass greater than 200 tons per hectare, equivalent to about 370 tons per hectare of $CO_2$ emissions if fully cleared. This implies an abatement cost of only a dollar or two per ton.[74]

Meanwhile, energy users in industrial countries who desire to abate the same amount of $CO_2$ at home—for voluntary reasons, or to meet a regulatory requirement—may end up spending considerably more. In today's nascent carbon market, buyers are paying $4.40 to $8 per ton to comply with national regulations, and some scenarios for a global carbon market predict substantially higher prices. The potential gains from trade appear to be large. By splitting the difference, energy users in the developed world could, in principle, save money in meeting their $CO_2$ reduction obligation, help maintain the many services and values of the tropical forest, and invest in a superior livelihood for the tropical farmer. As part of that livelihood improved soils and plantings would sequester even more $CO_2$.

There are many practical problems in realizing this vision, not least the danger that any particular plot of forest may eventually get burned or cut. But there are practical approaches to addressing these problems.[75] Most important, a global decision to invest in a portfolio of forest and agriculture carbon sinks diversifies this risk. Running these investments through locally controlled landscape management institutions ensures that the arrangements are acceptable. And it also helps shape the long-term incentives for agricultural intensification that averts the long-term pressure for deforestation.

### *Act now to reduce emissions over the medium and long terms*

Actions now to affect the evolution of the capital stock—vehicles, buildings, and generators—can yield huge and long-lasting reductions in GHG emissions and improvements in economic efficiency. Producing this equipment generates vast amounts of emissions. And once in place the equipment drives emissions for decades. Turnover times are about 10 years for vehicles, 30–50 years for power plants, and 80 years for residential buildings. This means great opportunities for reducing long-term emissions and fuel costs by using energy efficient technologies to expand the capital stock, or to replace equipment that is being retired.

The opportunities are particularly great for developing countries, which will be investing massively in long-lived infrastructure as a keystone of development. Between 1997 and 2020 developing countries are expected to expand their electricity-generating capacity by a factor of 2.5, investing $1.7 trillion in new plants and perhaps more in transmission and distribution.[76] Of China's building stock in 2015, half is expected to be built between now and then.[77] Once erected, those buildings are likely to be in place for half a century or more. But current building practices use antiquated technologies that leak heat, do not allow users to adjust heat levels, and consume 50–100 percent more energy than buildings in similar climes elsewhere. The coal to heat these buildings already generates 350 million tons of $CO_2$ a year and much of northern China's unhealthful levels of sulfur dioxide ($SO_2$) and particulates. Clearly, a vigorous shift in building practices could have tremendous long-term benefits both for China and for the world's climate. According to a World Bank study, such a shift will take substantial reforms in energy policies so that consumers have an incentive to conserve energy, but in a way to protect the poorest. It will simultaneously require research, de-

velopment, and dissemination of improved building designs appropriate to local conditions.

Actions now can determine whether development paths "lock in" to high- or low-energy regimes, with self-reinforcing patterns of policy, infrastructure, capital, and lifestyle. Land-rich countries including Australia, Canada, and the United States have evolved energy-intensive lifestyles featuring low fuel prices and heavy reliance on automobiles.[78] Social norms, infrastructure placement, and relative prices discourage individuals from opting for lifestyles that consume fewer resources. And because individuals are locked in to high energy consumption, there is likely to be little political support for increasing energy prices to levels that reflect environmental impacts. Once this lock-in occurs, it may take a generation or more to change. Lock-in is prevalent in the energy supply sector as well. Coal dependence, for instance, creates infrastructure, communities, and powerful political constituencies, making it difficult to shift to less carbon-intensive fuel sources.

Over the longer term the atmosphere's level of greenhouse gases can be stabilized only by switching the world to zero-emission energy sources: wind power, solar power, renewable biomass, fusion, and fossil fuel (with equivalent physical sequestration of $CO_2$). A few, such as wind power in favorable locations, have good short-term prospects. But most of these technologies are thought to be decades from large-scale commercial realization—and then only if basic and applied research are more vigorously pursued. Historically, new energy technologies have taken half a century or more to displace earlier ones. Accelerated development and deployment of new technologies are therefore essential for substantial reductions of emissions in this century.

There is an urgent need to boost basic research in energy technologies. The lag times between basic research and large-scale commercial deployment are sobering. Private industry is not willing to undertake the necessary basic research in areas such as fusion, geological carbon sequestration, high-efficiency coal combustion, or high-efficiency building technologies for tropical climates. Moreover, there is at least anecdotal evidence of high returns to government funding even in relatively applied research. For instance, a $3 million public investment in technologies for efficient windows is projected to yield $15 billion in energy savings through 2015 in the United States alone.[79] Yet public funding for basic energy research has declined in Europe and the United States.[80] Only 21.8 percent of the energy research budgets of countries belonging to the International Energy Association is devoted to renewable energy and conservation.[81]

Increased funding for research could substantially advance the time at which low-emissions energy technologies are deployed and thereby reduce the burden of GHG emissions controls. This in turn could facilitate international agreements on such controls. New technologies could also provide a wide range of environmental benefits. Most important, new technologies—especially those related to energy use and efficiency—may be able to reduce the energy bill of the developing world. This provides a powerful rationale for collaborative global research on energy, involving scientists and engineers from both the developing and developed world. It also suggests efforts to ensure that technologies derived from this research are available on favorable terms to all.

### *International cooperation to reduce emissions*

Short horizon or long, these agendas require complementary actions now. Taxes and carbon markets have a number of advantages. They can provide price signals that spur cost-efficient energy conservation and forest conservation. These signals may provide the demand stimulus that drives renewable technologies such as wind power and solar power down the learning curve, making them competitive with fossil fuels in some areas. This mechanism can therefore support the development and transfer of technology adapted to developing countries. Properly set up, carbon markets (such as those envisioned under the Kyoto Protocol) can result in the decentralized transfer of resources and technology to sustainable development projects in developing and transition economies.

Initiatives to encourage the adoption of low-emission capital equipment, and development of low-emissions or efficient technologies, can complement carbon markets and carbon taxes. Imposing energy standards (for instance, on cars or buildings) could be economically inefficient, but such regulations might have advantages. They might fight market failures for which price remedies are not apt, such as a tendency for building developers to shift recurrent energy costs to ill-informed renters or buyers. Or they might prove to be more politically acceptable, and more amenable, to a long-term commitment

than taxes. And as more people switch to efficient equipment, it becomes easier to support tighter limits on emissions associated with carbon markets. Similarly, accelerating research on new technologies can nicely complement price policies and other policies that encourage rapid development, dissemination, and uptake of those technologies.

How can emissions reductions—beyond those that pay for themselves—be financed? This remains the most contentious issue in climate change mitigation. In carbon markets, for instance, the allocation of emission allowances determines who pays for reductions. In the view of many, equal per capita allocation of allowances across the world—perhaps entailing transfers from rich emitters to poor countries—would constitute an equitable allocation. But such an allocation rule, if imposed abruptly, might disrupt the rich emitters' economies and thus would not secure their participation in the scheme. On the other hand, a strong link between past emissions and current allowances, applied globally, would hurt the development prospects of poor nations and thus be unacceptable. Hybrid allocation schemes that blend per capita and "grandfathered" allocations and shift toward the former over time have been proposed as a compromise. Other alternatives include coordinated national carbon taxes, whereby each country retains the tax revenue and combinations of allowances and taxes, and the taxes serve as a "safety valve," limiting compliance costs if allowance prices rise too high. Agreements on burden sharing are stymied in part by uncertainty about the actual economic burden that any of these systems would entail.

The experience of the CLRTAP suggests that it may not be necessary to work out long-run burden-sharing formulas in great detail in advance. A practical alternative is to engage all parties by starting with confidence-building steps, while maintaining momentum to tackle progressively more ambitious goals, more difficult decisions, and longer-term commitments as options are better understood. It is urgent, however, to develop a framework that does not penalize nations or other actors that voluntarily reduce their emissions in advance of commitments.

### *Adapting to climate change*

The climate system has considerable inertia. Even if GHG emissions were magically halted today, the effect of past emissions would continue to raise temperatures and sea levels for centuries to come. It follows, then, that adaptation efforts are necessary—but the adaptation agenda has only begun to be addressed.

Some impacts of climate change are relatively predictable and will play out inexorably over coming decades. Dealing with them will require foresight, commitment, and resources. For instance, an obvious way to reduce vulnerability to a rise in the sea level is to avoid the emergence of large settlements in low-lying areas. However, it is generally difficult to exclude urban settlers from areas attractive to them. Adaptation considerations may therefore require larger current investments in developing settlement alternatives, as a complement to the protection of areas that are at increasing risk. Other long-horizon issues include advance planning to replace threatened water supplies, developing drought-resistant crop varieties, and maintaining biodiversity corridors so that wildlife can migrate in response to changing temperature.

An immediate and enduring effect of climate change is to increase climate-related risks, such as droughts, floods, and storms. This occurs both because the climate itself becomes more volatile and because the past becomes an ever less reliable guide to the future, especially for infrequent catastrophic events. A recent study found that large floods are becoming more frequent, as climate change models would predict.[82] This suggests that the cost of building (or insuring) infrastructure to a given risk standard (say, to withstand a once-in-100-years flood) is rising even now.

There is growing appreciation that developing countries, especially, are not dealing optimally with current weather-related risks, let alone future ones. So efforts to reduce current vulnerabilities will not only have immediate payoffs—they will increase the countries' capacity to deal with increasing vulnerabilities to climate change.

One emerging set of innovative coping mechanisms involves the use of long-term weather forecasting and insurance markets to mitigate the risks of extreme weather events. These events can be particularly devastating to poor rural dwellers, whose entire network of mutual support can be disabled by droughts, floods, and storms. An interesting by-product of global climate research has been the increasing ability to forecast seasonal climate patterns months in advance. For instance, sea temperatures in the eastern Pacific can be used to predict season-ahead climate in Zimbabwe and thus potentially

to help poor farmers optimize their planting decisions.[83] These predictions could also help marketing agents prepare for droughts, significantly reducing the impacts on household welfare.[84]

There is also more interest in using insurance markets to help poor farmers cope with weather risks—a role that traditional crop insurance has never been able to play well because of the costs of enrolling small farmers, measuring damages and processing claims, and avoiding moral hazard and adverse selection.[85] Weather insurance, in contrast, depends on easily measurable temperature and precipitation data—and facilitates reinsurance. A current International Finance Corporation pilot project is exploring the potential for this kind of insurance in the developing world. These initiatives underline the value of weather data as both local and global public goods.

Management of large-scale climate risks will become more important at the subnational and national scale. Indeed, the financial damages from weather-related catastrophes are increasing rapidly, though it is difficult to separate greater exposure from the higher frequency of extreme events. There is a strong role for individual nations, and the world at large, to insure poor vulnerable regions against these catastrophes, a role already filled (on an ad hoc and sometimes inadequate basis) through a patchwork of disaster relief responses. A key commitment problem in designing a more comprehensive system is providing adequate insurance without encouraging risk-seeking or environmentally damaging behavior, such as settlements in areas that are at risk of landslides, or agriculture in fragile areas.[86]

The most general and effective way to help vulnerable poor countries adapt to climate change is to promote rapid and sustainable development. Over the coming decades more vigorous growth rates and accelerated investments in human capital will shift these countries out of climate-sensitive sectors and improve their capacity to cope with climate-related risks.

## Conclusion

The distinctive feature of global problems is the lack of a central authority for coordination and enforcement. Despite this obstacle, there are encouraging examples of successful transnational institution building to tackle transborder environmental problems. Success has been greatest in cases such as stratospheric ozone and acid rain, where the problem can be made operational in precise technical terms; where international action can therefore focus on tightly defined interventions; and where the perceived benefits of collective action have been high, for key actors, relative to the cost. It will be more difficult for other environmental and social problems—where the relationship between action and impact is less well understood, and where the costs and benefits of action do not coincide. Yet an adaptive strategy of the type described in this chapter has much to recommend itself because the frequency and urgency of such problems is bound to increase as globalization progresses along many dimensions. The next chapter illustrates some ways of approaching the linkages among social, economic, and environmental issues within and between countries in a shrinking world.