from Lester R. Brown, *Plan B 2.0 Rescuing a Planet Under Stress and a Civilization in Trouble* (NY: W.W. Norton & Co., 2006).

8

Restoring the Earth

The health of an economy cannot be separated from that of its natural support systems. More than half the world's people depend directly on croplands, rangelands, forests, and fisheries for their livelihoods. Many more depend on forest product industries, leather goods industries, cotton and woolen textile industries, and food processing industries for their jobs.[1]

A strategy for eradicating poverty will not succeed if an economy's environmental support systems are collapsing. If croplands are eroding and harvests are shrinking, if water tables are falling and wells are going dry, if rangelands are turning to desert and livestock are dying, if fisheries are collapsing, if forests are shrinking, and if rising temperatures are scorching crops, a poverty-eradication program—no matter how carefully crafted and well implemented—will not succeed.

In Chapter 5, we discussed the deforestation, soil erosion, and the utter devastation of Haiti's countryside. After looking at the desperate situation in Haiti, Craig Cox, Director of the U.S.-based Soil and Water Conservation Society, wrote, "I was reminded recently that the benefits of resource conservation—at the most basic level—are still out of reach for many. Ecolog-

ical and social collapses have reinforced each other in a downward spiral into poverty, environmental degradation, social injustice, disease, and violence." Unfortunately, the situation Cox describes is no longer a rarity. It describes what lies ahead for more and more countries if we do not launch an earth restoration initiative.[2]

Restoring the earth will take an enormous international effort, one even larger and more demanding than the often-cited Marshall Plan that helped rebuild war-torn Europe and Japan. And such an initiative must be undertaken at wartime speed lest environmental deterioration translate into economic decline, just as it did for earlier civilizations that violated nature's thresholds and ignored its deadlines.

Protecting and Restoring Forests

Protecting the earth's 3.9 billion hectares of remaining forests and replanting those lost are both essential for restoring the earth's health, an important foundation for the new economy. Reducing rainfall runoff and the associated flooding and soil erosion, recycling rainfall inland, and restoring aquifer recharge depend on simultaneously reducing pressure on forests and on reforestation.[3]

There is a vast unrealized potential in all countries to lessen the demand pressure that is shrinking the earth's forest cover. In industrial nations the greatest opportunity lies in reducing the quantity of wood used to make paper, and in developing countries it depends on reducing fuelwood use.

The rates of paper recycling in the top 10 paper-producing countries range widely, from China and Italy on the low end, recycling 27 and 31 percent of the paper they use, to Germany and South Korea on the high end, at 72 and 66 percent. The recycling rate in Germany is high because the government has consistently emphasized paper recycling to reduce the flow to landfills. If every country recycled as much of its paper as Germany does, the amount of wood pulp used to produce paper worldwide would drop by one third.[4]

The United States, the world's largest paper consumer, is far behind Germany but is making some progress. Twenty years ago, roughly one fourth of the paper used in the United States was recycled. By 2003, the figure had reached 48 percent.[5]

The use of paper, perhaps more than any other single prod-

uct, reflects the throwaway mentality that evolved during the last century. There is an enormous possibility for reducing paper use simply by replacing facial tissues, paper napkins, disposable diapers, and paper shopping bags with reusable cloth alternatives.

The largest single demand on trees—the need for fuel—accounts for just over half of all wood removed from forests. Some international aid agencies, including the U.S. Agency for International Development (AID), have begun to sponsor fuelwood efficiency projects. One of AID's more promising national projects is the distribution of 780,000 new, highly efficient wood cookstoves in Kenya. Investing public resources in replacing outmoded inefficient cookstoves can earn handsome dividends in forest protection and regeneration, including the restoration of forest services.[6]

Over the longer term, developing alternative cooking fuels is the key to reducing forest pressure in developing countries. As the world shifts from a fossil-fuel-reliant economy to one based on wind, solar, and geothermal energy, it will be much easier for developing countries without fossil fuels to develop indigenous sources of renewable energy. Replacing firewood with solar thermal cookers, with electric hotplates fed by wind-generated electricity, or with some other energy source will lighten the load on forests.

Kenya is also the site of a solar cooker project sponsored by Solar Cookers International. These inexpensive cookers, made from cardboard and aluminum foil and costing $10 each, cook slowly, much like a crockpot. Requiring three hours of sunshine to cook a complete meal, they can greatly reduce firewood use at little cost. They can also be used to pasteurize water, thus saving lives.[7]

Earlier definitions of sustainable forestry focused only on the sustained production of forest products, but they now include sustaining forest services such as flood control. Despite the high value to society of intact forests, only about 290 million hectares of global forest area are legally protected from logging. An additional 1.4 billion hectares are economically unavailable for harvesting because of geographic inaccessibility or low-value wood. Of the remaining area available for exploitation, 665 million hectares are undisturbed by humans and nearly 900 million hectares are semi-natural and not in plantations.[8]

Forests that are protected by national decree are often safe-

guarded not so much to preserve the long-term wood supply capacity as to ensure that the forest can continue to provide services. Countries that provide legal protection for forests often do so after they have suffered the consequences of extensive deforestation. The Philippines, for example, has banned logging in all remaining old-growth and virgin forests largely because the country has become so vulnerable to flooding, erosion, and landslides. The country was once covered by rich stands of tropical hardwood forests, but after years of massive clearcutting, it lost both the forest's products and its services and became a net importer of forest products.[9]

Reed Funk, professor of plant biology at Rutgers University, believes the vast areas of deforested land can be used to grow trillions of genetically improved trees for food, mostly nuts, and for fuel. Funk sees nuts used to supplement meat as a source of high-quality protein in developing-country diets. He also sees trees grown on this deforested land, much of it now wasteland, being used for conversion into ethanol for automotive fuel.[10]

Although nongovernmental organizations (NGOs) have worked for years to protect forests from clearcutting, the World Bank has only recently begun to systematically consider sustainable forestry. In 1998, the Bank joined forces with the World Wide Fund for Nature to form the Alliance for Forest Conservation and Sustainable Use; by 2005 they had helped designate 50 million hectares of new forest protected areas and certify 22 million hectares of forest. In mid-2005, the Alliance announced a goal of reducing global deforestation rates to zero by 2020.[11]

There are several forest product certification programs that link environmentally conscious consumers with sustainable management of the forest where the product originates. Some programs are national while others are international; some originate with importing countries and others with exporters.

The most rigorous international program, one that is certified by a group of NGOs, is the Forest Stewardship Council (FSC). Some 57 million hectares of forests in 65 countries are certified by FSC-accredited bodies as responsibly managed. Among the leaders in certified forest area are Sweden, with 10 million hectares; Poland, with 6 million hectares; the United States, with nearly 5 million hectares; and Brazil and South Africa, with 3 million and 2 million hectares respectively.[12]

Forest plantations can reduce pressures on the earth's remaining forests as long as they do not replace old-growth forest. As of 2000, the world had 187 million hectares in forest plantations, an area less than 5 percent of the total 3.9 billion hectares in forest and equal to nearly one fourth of the 700 million hectares planted in grain. Tree plantations produce mostly wood for paper mills or for wood reconstitution mills. Increasingly, reconstituted wood is substituting for natural wood in the world lumber market as industry adapts to a shrinking supply of large logs from natural forests.[13]

Production of roundwood on plantations is estimated at 414 million cubic meters per year, accounting for 12 percent of world wood production. This means that the lion's share, some 88 percent of the world timber harvest, comes from natural forest stands.[14]

Five countries account for two thirds of tree plantations. China, which has little original forest remaining, is the largest, with Russia and the United States following. India and Japan are fourth and fifth. Brazil is further back, but is expanding fast. As tree farming expands, it is shifting geographically to the moist tropics. In contrast to grain yields, which tend to rise with distance from the equator and the longer summer growing days, tree plantation yields rise with proximity to the equator and year-round growing conditions. [15]

In eastern Canada, the average hectare of forest plantation produces 4 cubic meters per year. In the southeastern United States, where U.S. plantations are concentrated, the yield is 10 cubic meters. But in Indonesia, it is 25 cubic meters, and in Brazil, newer plantations may be close to 30 cubic meters. While corn yields in the United States are nearly triple those in Brazil, timber yields are the reverse, favoring Brazil by nearly 3 to 1. To satisfy a given demand for wood, Brazil requires only one third as much land as the United States, which helps explain why growth in pulp capacity is now concentrated in equatorial regions.[16]

Projections of future growth show that plantations are constrained by land scarcity. They can sometimes be profitably established on already deforested, often degraded, land, but they are more likely to come at the expense of existing forests. There is also competition with agriculture, since land that is suitable for crops is also good for growing trees. Water scarcity

is yet another constraint. Fast-growing plantations require abundant moisture.

Nonetheless, the U.N. Food and Agriculture Organization (FAO) projects that as plantation area expands and yields rise, the harvest could more than double during the next three decades. It is entirely conceivable that plantations could one day satisfy most of the world's demand for industrial wood, thus helping to protect the world's remaining forests.[17]

Historically, some highly erodible agricultural land in industrial countries has been reforested by natural regrowth. For example, New England, a geographically rugged region of the United States, was reforested beginning a century or so ago. Settled early by Europeans, this region was suffering from cropland productivity losses because soils were thin and the land was rocky, sloping, and vulnerable to erosion. As highly productive farmland opened up in the Midwest and the Great Plains during the nineteenth century, pressures on New England farmland lessened, permitting cropped land to return to forest. New England's forest cover has increased from a low of roughly one third two centuries ago to perhaps three fourths today, slowly regaining its original health and diversity.[18]

A somewhat similar situation exists now in parts of the former Soviet Union and in several East European countries. As central planning was replaced by market-based agriculture in the early 1990s, farmers on marginal land were forced to seek their livelihoods elsewhere. Precise figures are difficult to come by, but millions of hectares of farmland are now returning to forest.[19]

South Korea is in many ways a reforestation model for the rest of the world. When the Korean War ended, half a century ago, the mountainous country was largely deforested. Beginning around 1960, under the dedicated leadership of President Park Chung Hee, the South Korean government launched a national reforestation effort. Relying on the creation of village cooperatives, hundreds of thousands of people were mobilized to dig trenches and to create terraces for supporting trees on barren mountains. South Korea not only reclaimed denuded areas, it also supported the effort with the establishment of fuelwood forests. Se-Kyung Chong, researcher at the Korea Forest Research Institute, writes, "The result was a seemingly miraculous rebirth of forests from barren land."[20]

Today forests cover 65 percent of the country, an area of roughly 8 million hectares. While driving across South Korea in November 2000, it was gratifying for me to see the luxuriant stand of trees on mountains that a generation ago were bare. We can reforest the earth![21]

In Turkey, a mountainous country largely deforested over millennia, a leading environmental group, TEMA (Türkiye Erozyona Mücadele, Agaclandirma), has made reforestation its principal activity. Founded by two prominent Turkish businessmen, Hayrettin Karuca and Nihat Gokyigit, TEMA launched in 1998 a 10-billion-acorn campaign to restore tree cover and reduce runoff and soil erosion. During the years since, 850 million oak acorns have been planted. The program is also raising national awareness of the services that forests provide.[22]

China is engaging in its own reforestation effort. In addition to planting trees in the recently deforested upper reaches of the Yangtze River basin to control flooding, China is planting a belt of trees to protect land from the expanding Gobi Desert. This green wall, a modern version of the Great Wall, is projected to reach some 4,480 kilometers (2,800 miles) in length, stretching from outer Beijing through Inner Mongolia. An ambitious, long-term plan, it is expected to take 70 years to complete and to cost up to $8 billion.[23]

Shifting subsidies from building logging roads to planting trees would help protect forest cover worldwide. The World Bank has the administrative capacity to lead an international program that would emulate South Korea's success in blanketing mountains and hills with trees.

In addition, FAO and the bilateral aid agencies can work with individual farmers in national agroforestry programs to integrate trees wherever possible into agricultural operations. Well-chosen, well-placed trees provide shade, serve as windbreaks to check soil erosion, and can fix nitrogen, reducing the need for fertilizer.

Reducing wood use by developing more-efficient wood stoves and alternative means of cooking, systematically recycling paper, and banning the use of throwaway paper products all lighten pressure on the earth's forests. A global reforestation effort cannot succeed unless it is accompanied by the stabilization of population. With such an integrated plan, coordinated country by country, the earth's forests can be restored.

Conserving and Rebuilding Soils

In reviewing the literature on soil erosion, references to the "loss of protective vegetation" occur again and again. Over the last half-century, we have removed so much of that protective cover by clearcutting, overgrazing, and overplowing that we are fast losing soil accumulated over long stretches of geological time. Eliminating these excesses and the resultant decline in the earth's biological productivity depends on a worldwide effort to restore the earth's vegetative cover, an effort that is now under way in some countries.

The 1930s Dust Bowl that threatened to turn the U.S. Great Plains into a vast desert was a traumatic experience that led to revolutionary changes in American agricultural practices, including the planting of tree shelterbelts—rows of trees planted beside fields to slow wind and thus reduce wind erosion—and strip-cropping, the planting of wheat on alternate strips with fallowed land each year. Strip cropping permits soil moisture to accumulate on the fallowed strips, while the alternating planted strips reduce wind speed and hence erosion on the idled land.[24]

In 1985, the U.S. Congress, with strong support from the environmental community, created the Conservation Reserve Program (CRP) to reduce soil erosion and control overproduction of basic commodities. By 1990 there were some 14 million hectares (35 million acres) of highly erodible land in permanent vegetative cover under 10-year contracts. Under this program, farmers were paid to plant fragile cropland to grass or trees. The retirement of 14 million hectares under the CRP, together with the use of conservation practices on 37 percent of all cropland, reduced U.S. soil erosion from 3.1 billion tons to 1.9 billion tons during the 15 years from 1982 to 1997. The U.S. approach to controlling soil erosion by both converting highly erodible cropland back to grassland or trees and adopting soil conservation practices offers a model for the rest of the world.[25]

The conversion of cropland to nonfarm uses is often beyond the control of farmers, but the losses of soil and eroded land from severe erosion are not. Lowering soil losses caused by wind and water erosion below the gains in new soil formed by natural processes will take an enormous worldwide effort. Preserving the biological productivity of highly erodible cropland depends on planting it in grass or trees before it becomes waste-

land. The first step in halting the decline in inherent land fertility is to pull back from this fast-deteriorating margin.[26]

Terracing, a time-tested method for dealing with water erosion, is common in rice paddies throughout the mountainous regions of Asia. On less steeply sloping land, contour strip farming, as found in the U.S. Midwest, works well.[27]

Another tool in the soil conservation toolkit—and a relatively new one—is conservation tillage, which includes both no-till and minimum tillage. In addition to reducing both wind and water erosion, this practice helps retain water, raises soil carbon content, and reduces the energy needed for crop cultivation.

Instead of the traditional cultural practices of plowing land, discing or harrowing it to prepare the seedbed, and then using a mechanical cultivator to control weeds in row crops, farmers simply drill seeds directly through crop residues into undisturbed soil, controlling weeds with herbicides. The only soil disturbance is the narrow slit in the soil surface where the seeds are inserted, leaving the remainder of the soil undisturbed, covered by crop residues and thus resistant to both water and wind erosion.[28]

In the United States, where farmers during the 1990s were required to implement a soil conservation plan on erodible cropland to be eligible for commodity price supports, the no-till area went from 7 million hectares in 1990 to 25 million hectares in 2004. Now widely used in the production of corn and soybeans in the United States, no-till has spread rapidly in the western hemisphere, covering 24 million hectares in 2004 in Brazil, 18 million hectares in Argentina, and 13 million in Canada. Australia, with 9 million hectares, rounds out the five leading no-till countries.[29]

Once farmers master the practice of no-till, its use can spread rapidly, particularly if governments provide economic incentives or require farm soil conservation plans for farmers to be eligible for crop subsidies. Recent FAO reports describe the early growth in no-till farming over the last few years in Europe, Africa, and Asia.[30]

Algeria, trying to halt the northward advance of the Sahara Desert, announced in December 2000 that it is concentrating its orchards and vineyards in the southern part of the country, hoping that these perennial plantings will halt the desertification of its cropland. In July 2005, the Moroccan government, respond-

ing to severe drought, announced that it was allocating $778 million to cancel farmers' debts and to convert cereal-planted areas into less vulnerable olive and fruit orchards."[31]

There are similar concerns about the expanding Sahara on the southern edge of the desert as well. President Olusegun Obasanjo of Nigeria has proposed planting a Great Green Wall of trees, a band five kilometers wide stretching 7,000 kilometers across Africa, in an effort to halt the desert's advance. Senegal, which is on the western end of this proposed wall and is losing 50,000 hectares of productive land each year, strongly supports the idea. No one knows how long this project would take, but Senegalese environment minister Modou Fada Diagne observes, "Poverty and desertification create a vicious cycle.…Instead of waiting for the desert to come to us, we need to attack it."[32]

As noted earlier, China also is trying to halt the advance of deserts with its Great Green Wall. In addition, it is paying farmers in the threatened provinces to plant their cropland in trees. The goal is to plant trees on 10 million hectares of grainland, easily one tenth of China's current grainland area.[33]

In Inner Mongolia (Nei Monggol), efforts to halt the advancing desert and to reclaim the land for productive uses rely on planting desert shrubs to stabilize the sand dunes. And in many situations, sheep and goats have been banned entirely. In Helin County, south of the provincial capital of Hohhot, the planting of desert shrubs on abandoned cropland has now stabilized the soil on the county's first 7,000-hectare reclamation plot. Based on this success, the reclamation effort is being expanded.[34]

The Helin County strategy centers on replacing the large number of sheep and goats with dairy cattle, increasing the number of dairy animals from 30,000 in 2002 to 150,000 by 2007. The cattle are kept in enclosed areas, feeding on cornstalks, wheat straw, and the harvest from a drought-tolerant forage crop resembling alfalfa, which is grown on reclaimed land. Local officials estimate that this program will double incomes within the county during this decade.[35]

To relieve pressure on the country's rangelands, Beijing is asking herders to reduce their flocks of sheep and goats by 40 percent. But in communities where wealth is measured in livestock numbers and where most families are living in poverty, such cuts are not easy or, indeed, likely, unless alternative liveli-

hoods are offered pastoralists along the lines proposed in Helin County.[36]

The only viable way to eliminate overgrazing on the two fifths of the earth's land surface classified as rangelands is to reduce the size of flocks and herds. Not only do the excessive numbers of cattle, and particularly sheep and goats, remove the vegetation, but their hoofs pulverize the protective crust of soil that is formed by rainfall and that checks wind erosion. In some situations, the only viable option is to keep the animals in enclosures, bringing the forage to them. India, which has successfully adopted this practice for its thriving dairy industry, is the model for other countries.[37]

Protecting the earth's remaining vegetation also warrants a ban on the clearcutting of forests in favor of selective harvesting, simply because with each clearcut there are heavy soil losses until the forest regenerates. Thus with each subsequent cutting, productivity declines further. Restoring the earth's tree and grass cover protects soil from erosion, reduces flooding, and sequesters carbon. It is one way we can restore the earth so that it can support our children and grandchildren.

Meeting Nature's Water Needs

There are many reasons for balancing water demand and supply. Failure to do so means that water tables will continue to fall, more rivers will run dry, and more lakes will disappear. If water tables are falling while energy prices are rising, irrigation water costs can rise to where farmers can no longer afford to irrigate. (Ways to raise irrigation efficiency are discussed in Chapter 9. Chapter 11 describes ways to reduce urban water waste.)

In *Rivers for Life: Managing Water for People and Nature*, Sandra Postel and Brian Richter cite South Africa's 1998 National Water Act as a model for other countries. The act focuses on two broad needs. The first is satisfying basic water needs of everyone for drinking, cooking, sanitation, and other essential purposes, which the legislation describes as a nonnegotiable allocation. The second is the water needed to support river ecosystem functions "in order to conserve biodiversity and secure the valuable ecosystem services they provide to society."[38]

Establishing minimal river flows so as to satisfy the specific needs of downstream aquatic ecosystems such as floodplains,

river deltas, and wetlands is not necessarily easy. For example, at times a strong flow is needed to meet the freshwater needs of an estuary. At other times, the needs of spawning fish may determine the ecological water needs.

A World Conservation Union–IUCN study in Australia notes that the Mowamba aqueduct has been permanently closed after 100 years of use in order to raise the flow of the Snowy River. This initial action, which raises the river flow from 3 percent of the natural level to 6 percent, is the first in a series of steps to bring the river flow back to 28 percent of the natural level and thus to restore its natural functions. In Australia's Murray-Darling basin, the enhanced flow of a river with releases from a storage facility in the basin helped to restore the natural wildlife population. The IUCN report noted, "the great egret bred for the first time since 1979, nine species of frog bred, as did native fish." [39]

Perhaps the best known and largest example of returning water to restore and support marine habitats occurred in California when the U.S. Congress passed legislation in 1992 that was designed to restore the overall health of the fish and wildlife habitat, including salmon runs, of the Sacramento-San Joaquin river system. Initially, as Sandra Postel reports in *Pillar of Sand*, Congress authorized the use of 800,000 acre-feet, nearly 1 billion cubic meters, or about 10 percent of the Central Valley Project's yearly water supply, for this purpose. Farmers who lost part of their irrigation water challenged the law.[40]

After several years of legal challenges and negotiations involving environmental groups, farmers, state government officials, and others, agreement was reached on an arrangement more or less consistent with the original congressional intent. The increased flow of the two rivers, which merge before emptying into San Francisco Bay, also helped protect the Bay's rich aquatic ecosystem, which is home to some 120 species of fish.[41]

Variations of these efforts to restore river flows to supply natural systems with the water they need are now commonplace. In the United States, literally hundreds of smaller dams are being demolished in an effort to restore river flows and natural systems, including spawning runs.[42]

In situations where growing water demand is exceeding the supply in more and more river basins, the challenge is to estab-

lish guidelines by which the various needs for water are met, recognizing that few will be fully met. Success hinges on having the institutions and a process by which water can be allocated among competing uses in a way that maximizes the contribution to society as a whole rather than to a small number of influential stakeholders at the expense of others.

Regenerating Fisheries

For decades governments tried to save specific fisheries by restricting the catch of individual species. Sometimes this worked; sometimes it failed and fisheries collapsed. In recent years, support for another approach—the creation of marine reserves or marine parks—has been gaining momentum. A network of marine reserves is defined as "a set of marine reserves within a biogeographic region, connected by larval dispersal and juvenile or adult migration." Reserves serve as natural hatcheries, helping to repopulate the surrounding area.[43]

In 2002, at the World Summit on Sustainable Development in Johannesburg, coastal nations pledged to create national networks of marine parks, which together could constitute a global network of such parks. At the World Parks Congress in Durban in 2003, delegates recommended protecting 20–30 percent of each marine habitat from fishing. This would be up from 0.5 percent of the oceans that are currently included in marine reserves of widely varying size. It compares with the 12 percent of the earth's land area that is in parks.[44]

A U.K. team of scientists led by Dr. Andrew Balmford of the Conservation Biology Group at Cambridge University analyzed the costs of operating marine reserves on a large scale based on data from 83 relatively small, well-managed reserves. They concluded that managing reserves that covered 30 percent of the world's oceans would cost $12–14 billion a year. This did not take into account the likely additional income from recovering fisheries, which would reduce the actual cost.[45]

At stake in the creation of a global network of marine reserves is the protection and possible increase of an annual oceanic fish catch worth $70–80 billion. Balmford said, "Our study suggests that we could afford to conserve the seas and their resources in perpetuity, and for less than we are now spending on subsidies to exploit them unsustainably."[46]

Coauthor of the U.K. study Callum Roberts, of the University of York, noted: "We have barely even begun the task of creating marine parks. Here in Britain a paltry one-fiftieth of one percent of our seas is encompassed by marine nature reserves and only one-fiftieth of their combined area is closed to fishing." Yet the seas are being devastated by unsustainable fishing, pollution, and mineral exploitation. The creation of the global network of marine reserves—"Serengetis of the seas," as some have dubbed them—would create more than 1 million jobs. Roberts went on to say, "If you put areas off limits to fishing, there is no more effective way of allowing things to live longer, grow larger, and produce more offspring."[47]

Jane Lubchenco, former President of the American Association for the Advancement of Science, strongly underlined Roberts' point when releasing a statement signed by 161 leading marine scientists calling for urgent action to create the global network of marine reserves. Drawing on the research of scores of marine parks, she said: "All around the world there are different experiences, but the basic message is the same: marine reserves work, and they work fast. It is no longer a question of *whether* to set aside fully protected areas in the ocean, but *where* to establish them."[48]

The signatories noted how quickly sea life improves once the reserves are established. A case study of a snapper fishery off the coast of New England showed that fishers, though they violently opposed the establishment of the reserve at first, now champion it because they have seen the local population of snapper increase 40-fold. In a study in the Gulf of Maine, all fishing methods that put ground fish at risk were banned within three marine reserves totaling 17,000 square kilometers. Unexpectedly, scallops flourished in this undisturbed environment, and their populations increased by 9–14 times within five years. This population buildup within the reserves also greatly increased the scallop population outside the reserves. The group of 161 scientists noted that within a year or two of establishing a marine reserve, population densities increased 91 percent, average fish size went up 31 percent, and species diversity rose 20 percent.[49]

While the creation of marine reserves is clearly the overriding priority in the long-standing effort to protect marine ecosystems, other measures are also required. One is to reduce the

nutrient flows from fertilizer runoff and untreated sewage. These increased nutrient flows cause huge algal blooms that then die off and in the process of decomposition absorb all the free oxygen in the water, leading to the death of local sea life. Today there are some 146 dead zones, either seasonal or chronic, scattered in the world's oceans from the Gulf of Mexico to the Baltic Sea to the east coast of China.[50]

The Gulf of Mexico dead zone near the mouth of the Mississippi River is one of the best known. This New Jersey–size area substantially reduces the marine diversity and yield of this historically productive body of water. Better control of nutrient runoff can be achieved through the adoption of such farming practices as minimum tillage and no-till, through the precise application of fertilizer to meet crop needs, and through planting buffer and filter strips along the Mississippi River and its tributaries.[51]

In the end, there is a need for governments to eliminate fishery subsidies. There are now so many fishing trawlers that their catch potential is nearly double any yield the oceans can sustain. Managing a network of marine reserves governing 30 percent of the oceans would cost only $12–14 billion—substantially less than the $15–30 billion that governments dole out today as subsidies to fishers.[52]

Protecting Plant and Animal Diversity

The two steps essential to protecting the earth's extraordinary biological diversity are the stabilization of population and climate. If the world's population increases to 9 billion by midcentury, countless more plant and animal species may simply be crowded off the planet. If carbon dioxide levels and temperatures continue to rise, every ecosystem will change.

Aiming for the low U.N. population trajectory, which has world population peaking at 7.8 billion in 2041 and then gradually declining, is the most effective option for protecting earth's rich diversity of life. As it becomes more difficult to raise land productivity, continuing population growth will force farmers to clear ever more tropical forests in the Amazon and Congo basins and the outer islands of Indonesia.[53]

Water management at a time of growing water shortages is a key in protecting marine species. When rivers are drained dry

to satisfy growing human needs for irrigation and for urban water, marine species cannot survive.

Perhaps the best known and most popular way of trying to protect plant and animal species is to create reserves. Millions of square kilometers have been set aside as parks. Indeed, some 12 percent of the earth's land area is now included in parks and nature preserves. With more resources, some of these parks in developing countries that now exist only on paper could become a reality.[54]

Some 15 years ago, Norman Myers and other scientists conceived the idea of biodiversity "hotspots"—areas that were especially rich biologically and thus deserving of special protection. This helped the World Wide Fund for Nature, Conservation International, The Nature Conservancy, and many other groups and governments to concentrate their preservation efforts. The 34 hotspots identified once covered nearly 16 percent of the earth's land surface, but largely because of habitat destruction they now cover less than 3 percent. Concentrating preservation efforts in these biologically rich regions was a step in the right direction.[55]

Some 30 years ago, the United States created the Endangered Species Act. This legislation prohibited any activities, such as clearing new land for agriculture and housing developments or draining wetlands, that would threaten an endangered species. There are numerous species in the United States, such as the bald eagle, that might now be extinct had it not been for this one piece of legislation.[56]

As a species humans have an enormous influence on the habitability of the planet for the millions of other species with which we share it. This influence brings with it an unprecedented responsibility.

The Earth Restoration Budget

Although we lack detailed data in some cases, we can roughly estimate how much it will cost to reforest the earth, protect the earth's topsoil, restore rangelands and fisheries, stabilize water tables, and protect biological diversity. Where data and information are lacking, we fill in with assumptions. The goal is not to have a set of precise numbers, but a set of reasonable estimates for an earth restoration budget. (See Table 8–1.)[57]

Calculating the cost of reforestation is complicated by the many approaches used. As noted, the big success story is South Korea, which over the last four decades has reforested its once denuded mountains and hills using locally mobilized labor. Other countries, including China, have tried extensive reforestation but mostly under more arid conditions and with much less success. Turkey has an ambitious NGO-led grassroots reforestation program, relying heavily on volunteer labor. So, too, does Kenya, where women's groups led by Nobel Peace Prize–winner Wangari Maathai have planted 30 million trees.[58]

In calculating reforestation costs, the focus is on developing countries since forested area is already expanding in the northern hemisphere's industrial countries. Meeting the growing fuelwood demand in these countries will require roughly an estimated 55 million additional hectares of forested area. Anchoring soils and restoring hydrological stability would require roughly another 100 million hectares located in thousands of watersheds in developing countries. Recognizing some overlap between these two, we will reduce the 155 million total to 150 million hectares. Beyond this, an additional 30 million hectares will be needed to produce lumber, paper, and other forest products.[59]

Only a small share of this tree planting will likely come from

Table 8–1. *Annual Earth Restoration Budget*

Activity	Funding
	(billion dollars)
Reforesting the earth	6
Protecting topsoil on cropland	24
Restoring rangelands	9
Restoring fisheries	13
Protecting biological diversity	31
Stabilizing water tables	10
Total	93

Source: See endnote 57.

plantations. Much of the planting will be on the outskirts of villages, along field boundaries, along roads, on small plots of marginal land, and on denuded hillsides. The labor for this will be local; some will be paid labor, some volunteer. Nearly all will be off-season labor. In China, farmers now planting trees where they once planted grain are compensated with grain from state-held stocks over a five-year period while the trees are becoming established.[60]

Reforestation is something of an uphill battle partly because the deforested land is often severely eroded and depleted of nutrients. Even the most dedicated nurturing does not guarantee high survival rates under marginal conditions.

If seedlings cost $40 per thousand, as the World Bank estimates, and if the typical planting rate is roughly 2,000 per hectare, then seedlings cost $80 per hectare. Labor costs for planting trees are high, but since much of the labor for planting these trees would consist of locally mobilized volunteers, we are assuming a total of $400 per hectare, including both seedlings and labor. With a total of 150 million hectares to be planted over the next decade, this will come to roughly 15 million hectares per year at $400 each for a total annual expenditure of $6 billion.[61]

Conserving the earth's topsoil by reducing erosion to the rate of new soil formation or below involves two principal steps. One is to retire the highly erodible land that cannot sustain cultivation—the estimated one tenth of the world's cropland that accounts for perhaps half of all erosion. For the United States, that has meant retiring 14 million hectares (nearly 35 million acres). The cost of keeping this land out of production is close to $50 per acre or $125 per hectare. In total, annual payments to farmers to plant this land in grass or trees under 10-year contracts approached $2 billion.[62]

The second initiative consists of adopting conservation practices on the remaining land that is subject to excessive erosion—that is, erosion that exceeds the natural rate of new soil formation. The initiative includes incentives to encourage farmers to adopt conservation practices such as contour farming, strip cropping, and, increasingly, minimum-till or no-till farming. These expenditures in the United States total roughly $1 billion per year.[63]

In expanding these estimates to cover the world, it is

assumed that roughly 10 percent of the world's cropland is highly erodible and should be planted to grass or trees before the topsoil is lost and it becomes barren land. In both the United States and China, the two leading food-producing countries, which account for a third of the world grain harvest, the official goal is to retire one tenth of all cropland. In Europe, it likely would be somewhat less than 10 percent, but in Africa and the Andean countries it could be substantially higher than that. For the world as a whole, converting 10 percent of cropland that is highly erodible to grass or trees seems a reasonable goal. Since this costs roughly $2 billion in the United States, which represents one eighth of the world cropland area, the total for the world would be roughly $16 billion annually.[64]

Assuming that the need for erosion control practices for the rest of the world is similar to that in the United States, we again multiply the U.S. expenditure by eight to get a total of $8 billion for the world as a whole. The two components together—$16 billion for retiring highly erodible land and $8 billion for adopting conservation practices—give an annual total for the world of $24 billion.[65]

For cost data on rangeland protection and restoration, we turn to the United Nations Plan of Action to Combat Desertification. This plan, which focuses on the world's dryland regions, containing nearly 90 percent of all rangeland, estimates that it would cost roughly $183 billion over a 20-year restoration period—or $9 billion per year. The key restoration measures include improved rangeland management, financial incentives to eliminate overstocking, and revegetation with appropriate rest periods, when grazing would be banned.[66]

This is a costly undertaking, but every dollar invested in rangeland restoration yields a return of $2.50 in income from the increased productivity of the rangeland ecosystem. From a societal point of view, countries with large pastoral populations, where the rangeland deterioration is concentrated, are invariably among the world's poorest. The alternative to action—ignoring the deterioration—brings not only a loss of land productivity, but ultimately millions of refugees, some migrating to nearby cities and others moving to other countries.[67]

The restoration of oceanic fisheries centers primarily on the

establishment of a worldwide network of marine reserves, which would cover roughly 30 percent of the ocean's surface. For this exercise we use the detailed calculations by the U.K. team cited earlier in the chapter. Their estimated range of expenditures centers on $13 billion per year.[68]

For wildlife protection, the bill is somewhat higher. The World Parks Congress estimates that the annual shortfall in funding needed to manage and to protect existing areas designated as parks comes to roughly $25 billion a year. Additional areas needed, including those encompassing the biologically diverse hotspots not yet included in designated parks, would cost perhaps another $6 billion a year, yielding a total of $31 billion.[69]

There is one activity, stabilizing water tables, where we do not have an estimate, only a guess. The key to stabilizing water tables is raising water productivity, and for this we have the experience gained beginning a half-century ago when the world started to systematically raise land productivity. The elements needed in a comparable water model are research to develop more water-efficient irrigation practices and technologies, the dissemination of these research findings to farmers, and economic incentives that encourage farmers to adopt and use these improved irrigation practices and technologies.

The area for raising irrigation water productivity is much smaller than that for land productivity. Indeed, only about one fifth of the world's cropland is irrigated. In disseminating the results of irrigation research, there are actually two options today. One is to work through agricultural extension services, which were created to funnel new information to farmers on a broad range of issues, including irrigation. Another possibility is to work through the water users associations that have been formed in many countries. The advantage of the latter is that they are focused exclusively on water.[70]

Effectively managing underground water supplies requires knowledge of the amount of water being pumped and aquifer recharge rates. In most countries this information is simply not available. Finding out how much is pumped may mean installing meters on irrigation well pumps, much as has been done in Jordan and Mexico.[71]

In some countries, the capital needed to fund a program to

raise water productivity can come from cancelled subsidies that now often encourage the wasteful use of irrigation water. Sometimes these are power subsidies, as they are in India; other times they are subsidies that provide water at prices well below costs, as happens in the United States. In terms of additional resources needed worldwide, including the economic incentives for farmers to use more water-efficient practices and technologies, we assume it will take additional expenditures of $10 billion.[72]

Altogether, restoring the earth will require additional expenditures of $93 billion per year. Many will ask, Can the world afford this? But the only appropriate question is, Can the world afford to not make these investments?