8

Restoring the Earth

We depend on the earth's natural systems for goods, ranging from building materials to water, as well as for services—everything from flood control to crop pollination. Thus if croplands are eroding and harvests are shrinking, if water tables are falling and wells are going dry, if grasslands are turning to desert and livestock are dying, we are in trouble. If civilization's environmental support systems continue to decline, eventually civilization itself will follow.

The devastation caused by deforestation and the soil erosion that results is exemplified by Haiti, where more than 90 percent of the original tree cover is gone, logged for firewood and cleared for crops. When hurricanes whip through the island shared by Haiti and the Dominican Republic, the carnage is often more severe for Haiti simply because there are no trees there to stabilize the soil and prevent landslides and flooding.[1]

Reflecting on this desperate situation, Craig Cox, executive 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. Ecological 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 what lies ahead for more and more countries if we do not quickly take steps to reverse the damage we have caused.[2]

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

Protecting and Restoring Forests

Since 1990, the earth's forest cover has shrunk by more than 7 million hectares each year, with annual losses of 13 million hectares in developing countries and regrowth of almost 6 million hectares in industrial countries. Protecting the earth's nearly 4 billion hectares of remaining forests and replanting those already lost are both essential for restoring the earth's health—the foundation for the new economy. Reducing rainfall runoff and the associated soil erosion and flooding, recycling rainfall inland, and restoring aquifer recharge depend on both forest protection and reforestation.[3]

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

The use of paper, perhaps more than any other single product, 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.

First we reduce paper use, then we recycle as much as possible. The rates of paper recycling in the top 10 paper-producing countries range widely, from Canada and China on the low end, recycling just over a third of the paper they use, to Japan and Germany on the higher end, each at close to 70 percent, and

South Korea recycling an impressive 85 percent. The United States, the world's largest paper consumer, is far behind the leaders, but it has raised the share of paper recycled from roughly one fifth in 1980 to 55 percent in 2007. If every country recycled as much of its paper as South Korea does, the amount of wood pulp used to produce paper worldwide would drop by one third.[4]

The largest single demand on trees—fuelwood—accounts for just over half of all wood removed from the world's forests. Some international aid agencies, including the U.S. Agency for International Development (AID), are sponsoring fuelwood efficiency projects. One of AID's more promising projects is the distribution of 780,000 highly efficient cookstoves in Kenya that not only use far less wood than a traditional stove but also pollute less.[5]

Kenya is also the site of a project sponsored by Solar Cookers International, whose inexpensive cookers, made from cardboard and aluminum foil, cost $10 each. Requiring less than two hours of sunshine to cook a complete meal, they can greatly reduce firewood use at little cost and save women valuable time by freeing them from traveling long distances to gather wood. The cookers can also be used to pasteurize water, thus saving lives.[6]

Over the longer term, developing alternative energy sources is the key to reducing forest pressure in developing countries. Replacing firewood with solar thermal cookers or even with electric hotplates powered by wind, geothermal, or solar thermal energy will lighten the load on forests.

Despite the high ecological and economic 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 thus far not protected, 665 million hectares are virtually undisturbed by humans and nearly 900 million hectares are semi-natural and not in plantations.[7]

There are two basic approaches to timber harvesting. One is clearcutting. This practice, often preferred by logging companies, is environmentally devastating, leaving eroded soil and silted streams, rivers, and irrigation reservoirs in its wake. The

alternative is simply to cut only mature trees on a selective basis, leaving the forest intact. This ensures that forest productivity can be maintained in perpetuity. The World Bank has recently begun to systematically consider funding sustainable forestry projects. In 1997 the Bank joined forces with the World Wide Fund for Nature to form the Alliance for Forest Conservation and Sustainable Use. By the end of 2005 they had helped designate 56 million hectares of new forest protected areas and certify 32 million hectares of forest as being harvested sustainably. That year the Alliance also announced a goal of reducing global net deforestation to zero by 2020.[8]

Several forest product certification programs let environmentally conscious consumers know about the management practices in the forest where wood products originate. The most rigorous international program, certified by a group of nongovernmental organizations, is the Forest Stewardship Council (FSC). Some 114 million hectares of forests in 82 countries are certified by FSC-accredited bodies as responsibly managed. Among the leaders in FSC-certified forest area are Canada, with 27 million hectares, followed by Russia, the United States, Sweden, Poland, and Brazil.[9]

Forest plantations can reduce pressures on the earth's remaining forests as long as they do not replace old-growth forest. As of 2005, the world had 205 million hectares in forest plantations, almost one third as much as the 700 million hectares planted in grain. Tree plantations produce mostly wood for paper mills or for wood reconstitution mills. Increasingly, reconstituted wood is substituted for natural wood as the world lumber and construction industries adapt to a shrinking supply of large logs from natural forests.[10]

Production of roundwood (logs) on plantations is estimated at 432 million cubic meters per year, accounting for 12 percent of world wood production. Six countries account for 60 percent of tree plantations. China, which has little original forest remaining, is by far the largest, with 54 million hectares. India and the United States follow, with 17 million hectares each. Russia, Canada, and Sweden are close behind. As tree farming expands, it is starting to shift geographically to the moist tropics. In contrast to grain yields, which tend to rise with distance from the equator and with longer summer growing days, yields from tree plantations are higher with the year-round growing conditions found closer to the equator.[11]

In eastern Canada, for example, the average hectare of forest plantation produces 4 cubic meters of wood per year. In the southeastern United States, the yield is 10 cubic meters. But in Brazil, newer plantations may be getting close to 40 cubic meters. While corn yields in the United States are nearly triple those in Brazil, timber yields are the reverse, favoring Brazil by nearly four to one.[12]

Plantations can sometimes be profitably established on already deforested and often degraded land. But they can also come at the expense of existing forests. And there is competition with agriculture, since land that is suitable for crops is also good for growing trees. Since fast-growing plantations require abundant moisture, water scarcity is another constraint.

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 protect the world's remaining forests.[13]

Historically, some highly erodible agricultural land in industrial countries was reforested by natural regrowth. Such is the case for New England in the United States. Settled early and cleared by Europeans, this geographically rugged region suffered 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 four fifths today, slowly regaining its original health and diversity.[14]

A somewhat similar situation exists now in parts of the former Soviet Union and in several East European countries. As centrally planned agriculture was replaced by market-based agriculture in the early 1990s, unprofitable marginal land was abandoned. Precise figures are difficult to come by, but millions of hectares of low-quality farmland there are now returning to forest.[15]

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 formation of village cooperatives, hundreds of thousands of people were mobilized to dig trenches and to create terraces for supporting trees on barren mountains. Se-Kyung Chong, researcher at the Korea Forest Research Institute, writes, "The result was a seemingly miraculous rebirth of forests from barren land."[16]

Today forests cover 65 percent of the country, an area of roughly 6 million hectares. While driving across South Korea in November 2000, it was gratifying to see the luxuriant stands of trees on mountains that a generation ago were bare. We can reforest the earth![17]

In Turkey, a mountainous country largely deforested over the millennia, a leading environmental group, TEMA (Türkiye Erozyonla Mücadele, Agaclandirma), has made reforestation its principal activity. Founded by two prominent Turkish businessmen, Hayrettin Karaca and Nihat Gökyigit, TEMA launched in 1998 a 10-billion-acorn campaign to restore tree cover and reduce runoff and soil erosion. Since then, 850 million oak acorns have been planted. The program is also raising national awareness of the services that forests provide.[18]

Reed Funk, professor of plant biology at Rutgers University, believes the vast areas of deforested land can be used to grow trillions of trees bred for food (mostly nuts), fuel, and other purposes. Funk sees nuts used to supplement meat as a source of high-quality protein in developing-country diets.[19]

In Niger, farmers faced with severe drought and desertification in the 1980s began leaving some emerging acacia tree seedlings in their fields as they prepared the land for crops. As the trees matured they slowed wind speeds, thus reducing soil erosion. The acacia, a legume, fixes nitrogen, thereby enriching the soil and helping to raise crop yields. During the dry season, the leaves and pods provide fodder for livestock. The trees also supply firewood.[20]

This approach of leaving 20–150 tree seedlings per hectare to mature on some 3 million hectares has revitalized farming communities in Niger. Assuming an average of 40 trees per hectare reaching maturity, this comes to 120 million trees. This practice also has been central to reclaiming 250,000 hectares of abandoned cropland. The key to this success story was the shift in tree ownership from the state to individual farmers, giving them the responsibility for protecting the trees.[21]

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, which reduces the need for fertilizer.

Reducing wood use by developing more-efficient wood stoves and alternative cooking fuels, systematically recycling paper, and banning the use of throwaway paper products all lighten pressure on the earth's forests. But a global reforestation effort is unlikely to 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.

Planting Trees to Sequester Carbon

In recent years the shrinkage of forests in tropical regions has released 2.2 billion tons of carbon into the atmosphere annually. Meanwhile, expanding forests in the temperate regions are absorbing close to 700 million tons of carbon. On balance, therefore, some 1.5 billion tons of carbon are being released into the atmosphere each year from forest loss, contributing to climate change.[22]

Tropical deforestation in Asia is driven primarily by the fast-growing demand for timber and, increasingly, by the soaring use of palm oil for fuel. In Latin America, by contrast, the growing market for soybeans, beef, and sugarcane ethanol is deforesting the Amazon. In Africa, it is mostly the gathering of fuelwood and the clearing of new land for agriculture as existing cropland is degraded and abandoned. Two countries, Indonesia and

Brazil, account for more than half of all deforestation and thus have the highest potential for avoiding emissions from clearing forests. The Democratic Republic of the Congo, also high on the list, is considered a failing state, making forest management there particularly difficult.[23]

The Plan B goals are to end net deforestation worldwide and to sequester carbon through a variety of tree planting initiatives and the adoption of improved agricultural land management practices. Today, because the earth's forests are shrinking, they are a major source of carbon dioxide (CO_2). The goal is to expand the earth's tree cover, growing more trees to soak up CO_2.

Although banning deforestation may seem farfetched, environmental reasons have pushed three countries—Thailand, the Philippines, and China—to implement complete or partial bans on logging. All three bans were imposed following devastating floods and mudslides resulting from the loss of forest cover. The Philippines, for example, has banned logging in most 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 the forest's products as well as its services and became a net importer of forest products.[24]

In China, after suffering record losses from several weeks of nonstop flooding in the Yangtze River basin in 1998, the government noted that when forest policy was viewed not through the eyes of the individual logger but through those of society as a whole, it simply did not make economic sense to continue deforesting. The flood control service of trees standing, they said, was three times as valuable as the timber from trees cut. With this in mind, Beijing then took the unusual step of paying the loggers to become tree planters—to reforest instead of deforest.[25]

Other countries cutting down large areas of trees will also face the environmental effects of deforestation, including flooding. If Brazil's Amazon rainforest continues to shrink, it may also continue to dry out, becoming vulnerable to fire. If the Amazon rainforest were to disappear, it would be replaced largely by desert and scrub forestland. The capacity of the rainforest to cycle water to the interior of the continent, including to the agricultural areas in the west and to the south, would be lost. At this point, a fast-unfolding local environmental calamity would become a global economic disaster, and, because the burning Amazon would release billions of tons of carbon into the atmosphere, it would become a global climate disaster.[26]

Just as national concerns about the effects of continuing deforestation eventually eclipsed local interests, deforestation has become a global challenge. It is no longer just a matter of local flooding. Because it drives climate change, deforestation is a matter of melting mountain glaciers, crop-shrinking heat waves, rising seas, and the many other effects of climate change worldwide. Nature has just raised the ante on protecting forests.

Reaching a goal of zero net deforestation will require reducing the pressures that come from population growth, rising affluence, growing biofuel consumption, and the fast-growing use of paper and wood products. Protecting the earth's forests means halting population growth as soon as possible. And for the earth's affluent residents who are responsible for the growing demand for beef and soybeans that is deforesting the Amazon basin, it means moving down the food chain and eating less meat. Ending deforestation may require a ban on the construction of additional biodiesel refineries and ethanol distilleries.

Because of the importance of forests in modulating climate, the Intergovernmental Panel on Climate Change (IPCC) has examined the potential for tree planting and improved forest management to sequester CO_2. Since every newly planted tree seedling in the tropics removes an average of 50 kilograms of CO_2 from the atmosphere each year during its growth period of 20–50 years, compared with 13 kilograms of CO_2 per year for a tree in the temperate regions, much of the afforestation and reforestation opportunity is found in tropical countries.[27]

Estimates vary widely on the full potential for tree planting to sequester carbon. Looking at global models, the IPCC notes that on the high end, tree planting and improved forest management could sequester some 2.7 billion tons of carbon (9.8 billion tons CO_2) per year by 2030 at a carbon price of less than \$367 per ton (\$100 per ton of CO_2). Nearly two thirds of that potential—or roughly 1.7 billion tons per year—is thought to be achievable at half that carbon price. Plan B, with its 2020 timeline, cuts the IPCC sequestration figure in half, to get 860 million tons of carbon sequestered per year by 2020 at a carbon price below \$200 per ton.[28]

To achieve this goal, billions of trees would need to be planted on millions of hectares of degraded lands that had lost their tree cover and on marginal cropland and pastureland that was no longer productive. Spread over a decade, to reach annual sequestration rates of 860 million tons of carbon by 2020, this would mean investing \$17 billion a year to give climate stabilization a large and potentially decisive boost.

This global forestation plan to remove atmospheric CO_2, most of it put there by industrial countries, would need to be funded by them. In comparison with other mitigation strategies, stopping deforestation and planting trees are relatively inexpensive. They pay for themselves many times over. An independent body could be set up to administer and monitor the vast tree planting initiative. The key is moving quickly to stabilize climate before temperature rises too high, thus giving these trees the best possible chance of survival.[29]

There are already many tree planting initiatives proposed or under way that are driven by a range of concerns, from climate change and desert expansion to soil conservation and making cities more habitable.

Kenyan Nobel laureate Wangari Maathai, who years ago organized women in Kenya and several nearby countries to plant 30 million trees, inspired the Billion Tree Campaign that is managed by the United Nations Environment Programme (UNEP). The initial goal was to plant 1 billion trees in 2007. If half of those survive, they will sequester 5.6 million tons of carbon per year. As soon as this goal was reached, UNEP set a new goal of planting 7 billion trees by the end of 2009—which would mean planting a tree for every person on earth in three years. As of July 2009, pledges toward the 7 billion plantings had passed 6.2 billion, with 4.1 billion trees already in the ground.[30]

Among the leaders in this initiative are Ethiopia and Turkey, each with over 700 million trees planted. Mexico is a strong third, with some 537 million trees. Kenya, Cuba, and Indonesia have each planted 100 million or more seedlings. Some state and provincial governments have also joined in. In Brazil, the state of Paraná, which launched an effort to plant 90 million trees in 2003 to restore its riparian zones, committed to planting 20 million trees in 2007. Uttar Pradesh, India's most populous state, mobilized 600,000 people to plant 10.5 million trees in a single day in July 2007, putting the trees on farmland, in state forests, and on school grounds.[31]

Many of the world's cities are also planting trees. Tokyo, for example, has been planting trees and shrubs on the rooftops of buildings to help offset the urban heat island effect and cool the city. Washington, D.C., is in the early stages of an ambitious campaign to restore its tree canopy.[32]

An analysis of the value of planting trees on the streets and in the parks of five western U.S. cities—from Cheyenne in Wyoming to Berkeley in California—concluded that for every $1 spent on planting and caring for trees, the benefits to the community exceeded $2. A mature tree canopy in a city shades buildings and can reduce air temperatures by 5–10 degrees Fahrenheit, thus reducing the energy needed for air conditioning. In cities with severe winters like Cheyenne, the reduction of winter wind speed by evergreen trees cuts heating costs. Real estate values on tree-lined streets are typically 3–6 percent higher than where there are few or no trees.[33]

Planting trees is just one of many activities that will remove meaningful quantities of carbon from the atmosphere. Improved grazing practices and land management practices that increase the organic matter content in soil also sequester carbon.

Conserving and Rebuilding Soils

The literature on soil erosion contains countless references to the "loss of protective vegetation." Over the last half-century, people have removed so much of that protective cover by clearcutting, overgrazing, and overplowing that the world is quickly losing soil accumulated over long stretches of geological time. Preserving the biological productivity of highly erodible cropland depends on planting it in grass or trees before it becomes wasteland.

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.[34]

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 with permanent vegetative cover under 10-year contracts. Under this program, farmers were paid to plant fragile cropland to grass or trees. The retirement of those 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 between 1982 and 1997. The U.S. approach offers a model for the rest of the world.[35]

Another tool in the soil conservation toolkit—and a relatively new one—is conservation tillage, which includes both no-till and minimum tillage. Instead of the traditional cultural practices of plowing land and 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. In addition to reducing erosion, this practice retains water, raises soil carbon content, and greatly reduces energy use for tillage.[36]

In the United States, where farmers during the 1990s were required to implement a soil conservation plan on erodible cropland in order to be eligible for commodity price supports, the no-till area went from 7 million hectares in 1990 to 27 million hectares (67 million acres) in 2007. Now widely used in the production of corn and soybeans, no-till has spread rapidly in the western hemisphere, covering 26 million hectares in Brazil, 20 million hectares in Argentina, and 13 million in Canada. Australia, with 12 million hectares, rounds out the five leading no-till countries.[37]

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 growth in no-till farming over the last few years in Europe, Africa, and Asia.[38]

A number of these agricultural practices can have the added benefit of increasing the carbon stored as organic matter in soils. Farming practices that reduce soil erosion and raise cropland productivity usually also lead to higher carbon content in the soil. Among these are the shift to minimum-till and no-till farming, the more extensive use of cover crops, the return of all livestock and poultry manure to the land, expansion of irrigated area, a return to more mixed crop-livestock farming, and the forestation of marginal farmlands.

Other approaches are being used to halt soil erosion and desert encroachment on cropland. In July 2005, the Moroccan government, responding to severe drought, announced that it was allocating $778 million to canceling farmers' debts and converting cereal-planted areas into less vulnerable olive and fruit orchards.[39]

Sub-Saharan Africa faces a similar situation, with the desert moving southward all across the Sahel, from Mauritania and Senegal in the west to the Sudan in the east. Countries are concerned about the growing displacement of people as grasslands and croplands turn to desert. As a result, the African Union has launched the Green Wall Sahara Initiative. This plan, originally proposed by Olusegun Obasanjo when he was president of Nigeria, calls for planting 300 million trees on 3 million hectares in a long band stretching across Africa. Senegal, which is currently losing 50,000 hectares of productive land each year, would anchor the green wall on the western end. Senegal's Environment Minister Modou Fada Diagne says, "Instead of waiting for the desert to come to us, we need to attack it." Since the initiative was launched, its scope has broadened to include improved land management practices such as rotational grazing.[40]

China is likewise 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 extend some 4,480 kilometers (2,800 miles), stretching from outer Beijing through Inner Mongolia (Nei Monggol). In addition to its Great Green Wall, China 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. Unfortunately, recent pressures to expand food production appear to have slowed this tree planting initiative.[41]

In Inner Mongolia, 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.[42]

The Helin County strategy centers on replacing the large number of sheep and goats with dairy cattle. The dairy herds are kept within restricted areas, feeding on cornstalks, wheat straw, and the harvest from a drought-tolerant forage crop resembling alfalfa, which is used to reclaim land from the desert. Local officials estimate that this program will double incomes within the county during this decade.[43]

To relieve pressure on China's rangelands as a whole, 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 livelihoods are offered to pastoralists along the lines proposed in Helin County.[44]

In the end, 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 naturally checks wind erosion. In some situations, the preferred option is to keep the animals in restricted areas, bringing the forage to them. India, which has successfully adopted this practice for its thriving dairy industry, is the model for other countries.[45]

Protecting the earth's soil also warrants a worldwide ban on the clearcutting of forests in favor of selective harvesting, simply because with each successive clearcut there are heavy soil losses until the forest regenerates. And with each subsequent cutting, more soil is lost and productivity declines further. Restoring the earth's tree and grass cover, as well as practicing conservation agriculture, protects soil from erosion, reduces flooding, and sequesters carbon.

Rattan Lal, a senior agronomist with the Carbon Management and Sequestration Center at Ohio State University, has calculated the range of potential carbon sequestration for many practices. For example, expanding the use of cover crops to protect soil during the off-season can store from 68 million to 338 million tons of carbon worldwide each year. Calculating the total carbon sequestration potential from this broad scope of practices, using the low end of the range for each, shows that 400 million tons of carbon could be sequestered each year. Aggregating the numbers from the more optimistic high end of the range for each practice yields a total of 1.2 billion tons of carbon per year. For our carbon budget we are assuming, perhaps conservatively, that 600 million tons of carbon can be sequestered as a result of adopting these carbon-sensitive farming and land management practices.[46]

Regenerating Fisheries

For decades governments have 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. These reserves, where fishing is banned, serve as natural hatcheries, helping to repopulate the surrounding area.[47]

In 2002, at the World Summit on Sustainable Development in Johannesburg, coastal nations pledged to create national networks of marine reserves or parks that would cover 10 percent of the world's oceans by 2012. Together these could constitute a global network of such parks.

Progress is slow. By 2006 there were 4,500 marine protected area (MPAs), most of them quite small, covering 2.2 million square kilometers, or less than 1 percent of the world's oceans. Of the area covered by MPAs, only 0.01 percent is covered by marine reserves where fishing is banned. And a survey of 255 marine reserves reported that only 12 were routinely patrolled to enforce the ban.[48]

Marine biologists are learning that there are biological hotspots that contain an unusual diversity of species in the oceans as well as on land. The challenge in marine conservation is first to identify these marine hotspots and breeding grounds and then to incorporate them into marine reserves.[49]

Among the more ambitious initiatives to create marine parks thus far are one by the United States and another by Kiribati. In 2006, President George W. Bush designated 140,000 square miles in the northwestern Hawaiian Islands as a marine park. Named the Papahānaumokuākea Marine National Monument, this one park is larger than all the U.S. land-based parks combined. It is home to over 7,000 marine species, one fourth of them found only in the Hawaiian archipelago. In early 2009, President Bush declared three more ecologically rich regions nearby also as national monuments, bringing the total protected area to 195,000 square miles, an area larger than the states of Washington and Oregon combined. Fishing is limited within these monument areas, and mining and oil drilling are prohibited.[50]

In early 2008, Kiribati, an island country of 98,000 people located in the South Pacific midway between Hawaii and New Zealand, announced what was at the time the world's largest marine protected area, covering some 158,000 square miles. Comparable in size to the state of California, it encompasses eight coral atolls, two submerged reefs, and a deep-sea tuna spawning ground.[51]

A U.K. team of scientists led by Dr. Andrew Balmford of the Conservation Science Group at Cambridge University has 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.[52]

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."[53]

Coauthor 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." Still 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 also 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."[54]

In 2001 Jane Lubchenco, former President of the American Association for the Advancement of Science and now head of the National Oceanic and Atmospheric Administration, released a statement signed by 161 leading marine scientists calling for urgent action to create the global network of marine reserves. Drawing on the research on 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."[55]

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, 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 groundfish 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 up to 14-fold within five years. This buildup within the reserves also greatly increased the scallop population outside the reserves. The 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.[56]

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 sewage that create the world's 400 or so oceanic dead zones, in effect "deserts of the deep." Another needed measure is to reduce the discharge of toxic chemicals, heavy metals, and endocrine disrupters directly into the water or indirectly through discharge into the atmosphere. Each of these discharges that build up in the oceanic food chain threaten not only predatory marine mammals, such as seals, dolphins, and whales, but also the large predatory fish, such as tuna and swordfish, as well as the humans who eat them.[57]

On a broader level, the buildup of atmospheric CO_2 is leading to acidification of the oceans, which could endanger all sea life. Most immediately threatened are the coral reefs, whose carbonate structure makes them highly vulnerable to the acidification that is under way and that is gaining momentum as CO_2 emissions increase. Protecting shallow water reefs that are invariably hotspots of plant and animal diversity may now depend on quickly phasing out coal-fired power plants, as does the attainment of so many other environmental goals.

In the end, governments need to eliminate fishery subsidies. Partly as a result of these subsidies, there are now so many fishing trawlers that their catch potential is nearly double the sustainable fish catch. Managing a network of marine reserves governing 30 percent of the oceans would cost only $12–14 billion—less than the $22 billion in harmful subsidies that governments dole out today to fishers.[58]

Protecting Plant and Animal Diversity

The two steps essential to protecting the earth's extraordinary biological diversity are stabilization of the human population and the earth's climate. If our numbers rise above 9 billion by mid-century, as projected, countless more plant and animal species may be crowded off the planet. If temperatures continue to rise, every ecosystem on earth will change.[59]

One reason we need to stabilize population at 8 billion by 2040 is to protect this 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.

Better water management, particularly at a time of growing water shortages, is a key to protecting freshwater and marine species. When rivers are drained dry to satisfy growing human needs for irrigation and for water in cities, fish and other aquatic 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 13 percent of the earth's land area is now included in parks and nature preserves. With more resources for enforced protection, some of these parks in developing countries that now exist only on paper could become a reality.[60]

Some 20 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. 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 is now a common strategy among conservation groups and governments.[61]

In 1973 the United States enacted 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. Numerous species in the United States, such as the bald eagle, might now be extinct had it not been for this legislation.[62]

Another promising school of thought centers on the extension of species conservation into agriculture, urban landscapes, roadways, and other landscapes. Among other things, this protects and strengthens wildlife corridors. Wildlife action plans for individual states, developed by the U.S. Fish and Wildlife Service, could be a template for this approach.

The traditional approach to protecting biological diversity by building a fence around an area and calling it a park or nature preserve is no longer sufficient. If we cannot also stabilize population and the climate, there is not an ecosystem on earth that we can save.

The Earth Restoration Budget

We can roughly estimate how much it will cost to reforest the earth, protect topsoil, restore rangelands and fisheries, stabilize water tables, and protect biological diversity. The goal is not to offer a set of precise numbers but to provide a set of reasonable estimates for an earth restoration budget. (See Table 8–1.)[63]

Calculating the cost of reforestation is complicated by the range of approaches used. As noted, the extraordinary reforestation success of South Korea was based almost entirely on locally mobilized labor. Other countries, including China, have tried extensive reforestation, but mostly under more arid conditions and with less success.[64]

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 developing countries will require an estimated 55 million additional hectares of forested area. Conserving 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

Table 8–1. *Plan B Budget: Additional Annual Funding Needed to Restore the Earth*

Activity	Funding (billion dollars)
Planting trees to reduce flooding and conserve soil	6
Planting trees to sequester carbon	17
Protecting topsoil on cropland	24
Restoring rangelands	9
Restoring fisheries	13
Protecting biological diversity	31
Stabilizing water tables	10
Total	110

Source: See endnote 63.

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.[65]

Only a small share of this tree planting will likely come from plantations. Much of the planting will be on the outskirts of villages, along field boundaries and 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. Much of it will be rural 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.[66]

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 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 an annual expenditure of $6 billion.[67]

Planting trees to conserve soil, reduce flooding, and provide firewood sequesters carbon. But because climate stabilization is essential, we tally the cost of planting trees for carbon sequestration separately. Doing so would reforest or afforest hundreds of millions of hectares of marginal lands over 10 years. Because it would be a more commercialized undertaking focused exclusively on wasteland reclamation and carbon sequestration, it would be more costly. Using the value of sequestered carbon of $200 per ton, it would cost close to $17 billion per year.[68]

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 excess 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.[69]

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. This 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.[70]

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 in 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 that together account for over a third of the world grain harvest, the official goal is to retire one tenth of all cropland. In Europe, it likely would be much less than 10 percent, but in Africa and the Andean countries it could be substantially higher. For the world as a whole, converting 10 percent of cropland that is highly erodible to grass or trees seems like 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.[71]

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.[72]

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, during which grazing would be banned.[73]

This is a costly undertaking, but every $1 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 a loss not only of land productivity but also of livelihood, and ultimately leads to millions of refugees. Though not quantified here, restoring this vulnerable land will also have carbon sequestration benefits.[74]

The restoration of oceanic fisheries centers primarily on the establishment of a worldwide network of marine reserves that 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.[75]

For wildlife protection, the bill is somewhat higher. The World Parks Congress estimates that the annual shortfall in funding needed to manage and 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.[76]

For stabilizing water tables, we have only a guess. The key to stabilizing water tables is raising water productivity, and for this we have the experience gained when the world started to systematically raise land productivity beginning a half-century ago. 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 to focus on 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.[77]

Effectively managing underground water supplies requires knowledge of the amount of water 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, as has been done in Jordan and Mexico.[78]

In some countries, the capital needed to fund a program to raise water productivity can come from eliminating subsidies that often encourage the wasteful use of irrigation water. Sometimes these are energy subsidies, as in India; other times they are subsidies that provide water at prices well below costs, as in the United States. Removing these subsidies will effectively raise the price of water, thus encouraging its more efficient use. In terms of additional resources needed worldwide, including research needs and the economic incentives for farmers to use more water-efficient practices and technologies, we assume it will take an annual expenditure of $10 billion.[79]

Altogether, then, restoring the earth will require additional expenditures of just $110 billion per year. Many will ask, Can the world afford these investments? But the only appropriate question is, Can the world afford the cost of not making these investments?