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3

Signs of Stress: The Biological Base

In April 2001, scientists at the National Oceanic and Atmospheric Administration laboratory in Boulder, Colorado, reported that a huge dust storm from northern China had reached the United States, "blanketing areas from Canada to Arizona with a layer of dust." People living in the foothills of the Rockies could not even see the mountains. Few Americans were aware that the dust on their cars and the haze hanging over the western United States was, in fact, soil from China.[1]

This Chinese dust storm, the most severe of a dozen in the spring of 2001, signals a widespread deterioration of the rangeland and cropland in that country's vast northwest. These huge dust plumes routinely travel hundreds of miles to populous cities in northeastern China, including Beijing—obscuring the sun, reducing visibility, slowing traffic, and closing airports. Reports of residents in eastern cities caulking windows with old rags to keep out the dust are reminiscent of the U.S. Dust Bowl of the 1930s.[2]

News reports in China typically attributed the dust storms to the drought of the last three years, but that has simply brought a fast-deteriorating situation into focus. Overgrazing and overplowing are widespread. For example, the United States, a country of com-

parable size and grazing capacity, has 98 million cattle and 9 million sheep and goats, whereas China now has 127 million cattle and 279 million sheep and goats. Feeding 1.3 billion people, a population nearly five times that of the United States, is not an easy matter. Millions of hectares of highly erodible land were plowed that should have stayed in grass.[3]

Evidence of the intensifying conflict between the economy and the ecosystem of which it is a part can be seen not only in the dust bowl emerging in China, but also in the burning rainforests in Indonesia, the collapsing cod fishery in the North Sea, falling crop yields in Africa, the expanding dead zone in the Gulf of Mexico, and falling water tables in India.

The ill-structured global economy's rising demands on ecosystems are diminishing the earth's biological productivity. The output of oceanic fisheries is reduced by overfishing, by oceanic pollutants, and by disruptions of the reproductive cycle of river-spawning fish as some rivers are dammed and others are drained dry. Overgrazing of rangelands is also taking a toll. Initially overgrazing reduces the productivity of rangelands, but eventually it destroys them—converting them into desert.

The productive capacity of the earth's forests is declining as they shrink by more than 9 million hectares per year. Lumbering, land clearing for crop production or ranching, and firewood gathering are responsible. Healthy rainforests do not burn, but fragmented tropical rainforests can be weakened to where they are easily ignited by lightning.[4]

An estimated 36 percent of the world's cropland is suffering a decline in inherent productivity from soil erosion. If this continues, eventually the cropland will become wasteland. In Africa, the failure to replace nutrients removed by crops is reducing crop yields in several countries. As local ecosystems deteriorate, the land's carrying capacity is reduced, setting in motion a self-reinforcing cycle of ecological degradation and deepening human poverty. With half the world's workforce dependent on croplands, fisheries, rangelands, and forests for their jobs and livelihood, any deterioration of these ecosystems can translate into a decline in living conditions.[5]

Fisheries Collapsing

Among the three ecosystems that supply our food—croplands, rangelands, and fisheries—the excessive demand on fisheries is perhaps most visible. After World War II, accelerating population growth and steadily rising incomes drove the demand for seafood upward at a record pace. At the same time, advances in fishing technologies, including refrigerated processing ships that enabled trawlers to exploit distant oceans, dramatically boosted fishing capacity.

In response, the oceanic fish catch climbed from 19 million tons in 1950 to its historic high of 93 million tons in 1997. This fivefold growth—more than double that of population during this period—raised seafood consumption per person worldwide from 8 kilograms in 1950 to a peak of 17 kilograms in 1988. Since then, it has fallen to scarcely 15 kilograms, a drop of one eighth.[6]

Oceanic fisheries were long a leading source of animal protein in the diet of island countries and those with long coastlines, such as Norway and Italy, but it was not until the second half of the twentieth century that fishing fleets began to systematically exploit the oceanic food potential. This, combined with improved inland transportation and refrigeration, made seafood a basic component of diets for most of humanity.

In the early 1990s, the U.N. Food and Agriculture Organization (FAO), which monitors oceanic fisheries, reported that all of the world's 17 major fisheries were being harvested at or beyond their sustainable capacity and that 9 were in a state of decline. Many countries were trying to protect their fisheries from overfishing and eventual collapse. In 1992, Canada, which had waited too long to restrict the catch in its 500-year-old cod fishery off the coast of Newfoundland, was forced to suspend fishing there entirely, putting some 40,000 fishers and fish processors out of work. Then in late 1993, Canada closed additional stretches of water to cod fishing, with the off-limits area creeping down toward the U.S. coast. The United States followed with restrictions designed to save its cod, haddock, and flounder fisheries off New England.[7]

On the West coast, conditions were no better. In April 1994, the Pacific Fishery Management Council banned salmon fishing off Washington State in an effort to protect the species from extinction. In Oregon and California, stringent salmon quotas were imposed. Actions by the United States and Canada, combined with

similar measures by governments elsewhere, implicitly acknowledge that unrestricted harvesting could destroy fisheries, depriving the world of a valuable food source.[8]

The inability of governments to cooperate in oceanic fishery management means that instead of yielding maximum sustainable catch indefinitely, many fisheries have been fished to the verge of collapse. Atlantic stocks of the heavily fished bluefin tuna, a standby in Tokyo's sushi restaurants, have been cut by a staggering 94 percent. It will take years for such long-lived species to recover, even if fishing stops altogether.[9]

Inland fisheries are also suffering from environmental mismanagement—water diversion, acidification, and pollution. As noted in Chapter 2, the Aral Sea fishery, which yielded 60,000 tons (close to 130 million pounds) of fish per year as recently as 1960, is now history. Rising salt content has left the sea biologically dead.[10]

A June 2001 report indicates that Russia's Azov Sea is also dying. Rising levels of salt, petroleum wastes, heavy metal pollution, and radioactive materials are apparently involved. The commercial fish catch has dropped 97 percent over the last quarter-century. Many species are extinct. As one commentator noted, the Sea of Azov has become "a body of water that cannot support either life within it or the lives of the people who live around it."[11]

Acidification of lakes from acid rain, largely from coal burning, is also still a problem. Canada alone now counts 14,000 dead lakes. And pollution is taking a toll on freshwater lakes, either destroying the fish or rendering them unsafe for human consumption. In the United States, fish in some 50,000 freshwater lakes, streams, and ponds contain levels of mercury that make them unsafe for human consumption. Mercury from the smokestacks of coal-fired power plants is largely responsible. (See Chapter 6.)[12]

Overfishing and pollution are not the only threats to the world's seafood supply. The spawning grounds and nurseries of many aquatic creatures are disappearing as coastal wetlands, mangrove forests, and coral reefs are destroyed. In addition, the damming of rivers is depriving many species of their spawning grounds. Other rivers are drained dry, with the same effect. Still others are simply too polluted for fish to survive.

Some 90 percent of oceanic fish rely on coastal wetlands, mangrove swamps, or rivers as spawning areas. Well over half the original area of mangrove forests in tropical and subtropical countries

has been lost. The disappearance of coastal wetlands in industrial countries is even greater. In Italy, whose coastal wetlands are the nurseries for many Mediterranean fisheries, the loss is a staggering 95 percent.[13]

Damage to coral reefs, a breeding ground for fish in tropical and subtropical waters, is also taking a toll. Between 1992 and 2000, the share of severely damaged reefs worldwide expanded from 10 percent to 27 percent. As the reefs deteriorate, so do the fisheries that depend on them.[14]

Oceanic fisheries face numerous threats, but it is overfishing that most directly threatens their survival. Oceanic harvests expanded as new technologies evolved, ranging from sonar for tracking schools of fish to vast driftnets that are collectively long enough to circle the earth many times over. "With more powerful boats and fish finders, we basically have the capacity to wipe fish out, and we are," warns Douglas Foy of the Conservation Law Foundation in New England.[15]

Commercial fishing is now largely an economics of today versus tomorrow. Governments are seeking to protect tomorrow's catches by forcing fishers to keep their ships idle; fishing communities are torn between the need for income today versus the future. Ironically, one reason for excess fleet capacity is long-standing government subsidies that provide large loans and favorable terms for investing in new boats and fishing gear. By 2000, however, these loans had become unsupportable as catches dwindled. Catch quotas kept many fishing boats at anchor during what used to be peak fishing months.[16]

Fishing subsidies were based on an unfounded belief that past trends in oceanic harvests could be projected into the future—that past growth meant future growth. The long-standing advice of FAO marine biologists, who had warned that marine harvests would someday reach a limit, was largely ignored.[17]

As long as there were more fish in the oceans than we could hope to catch, managing oceanic fisheries was a simple matter. But with many fisheries already collapsing, and others facing imminent collapse, the management challenge of allocating the catch among competing nations and protein-hungry populations is infinitely more difficult. Merely sustaining the existing catch will require new levels of cooperation among national governments.

Even among countries accustomed to working together, such as

those in the European Union (EU), the challenge of negotiating catch limits at sustainable levels can be difficult. In April 1997, after prolonged negotiations, agreement was reached in Brussels to reduce the fishing capacity of EU fleets by 30 percent for endangered species, such as cod, herring, and sole in the North Sea, and by 20 percent for overfished stocks, such as cod in the Baltic Sea, the bluefin tuna, and swordfish off the Iberian peninsula. The good news was that the EU finally reached agreement on reducing the catch. The bad news was that these cuts were not sufficient to arrest the decline of the region's fisheries.[18]

In January 2001, the EU went further, announcing a ban on fishing for cod, haddock, and whiting during the 12-week spring spawning period. With the annual cod catch falling from 300,000 tons during the mid-1980s to 50,000 tons in 2000, this most recent step was a desperate effort to save the fishery. EU officials are all too aware that Canada's once-vast Newfoundland cod fishery has not recovered since collapsing in 1992, despite the total ban on fishing imposed then.[19]

When some fisheries collapse, it puts more pressure on those that are left. With restrictions on the overfished EU fishery, the heavily subsidized EU fishing fleet has turned to the west coast of Africa, buying licenses to fish off the coasts of Senegal, Mauritania, Morocco, Guinea-Bissau, and Cape Verde. They are competing for space there with fleets from Japan, South Korea, Russia, and China. For impoverished countries like Mauritania and Guinea-Bissau, income from fishing licenses can account for up to half of government revenue. Unfortunately for the Africans, their fisheries too are collapsing. Most countries lack the ships and radar to ensure compliance with fishing agreements in the 200-mile exclusive economic zones off their coasts that were granted by the 1979 Law of the Sea Treaty.[20]

Fisheries everywhere are facing the same fate. On the west coast of India, the fishery off the coast of Goa has grown by leaps and bounds as the mechanized fishing fleet has jumped from 10 boats in 1964 to 2,200 in 1998. Meanwhile, the annual catch increased from 17,000 tons to 95,000 tons—well beyond the estimated maximum sustainable yield of 71,000 tons. Unless the Indian government can quickly reduce the catch here to the sustainable level, this fishery too will collapse, depriving India's coastal population of a sorely needed source of protein.[21]

If the oceans cannot sustain a catch of more than 95 million tons and if world population continues to grow as projected, the oceanic fish catch per person—which has already declined 9 percent since it peaked in 1988—is likely to drop to 10 kilograms per person in 2050. The generation that came of age during World War II saw the fish catch per person double during their lifetimes. Their grandchildren, the children of today, may witness a one-third reduction.[22]

The bottom line is that the growing worldwide demand for seafood can no longer be satisfied from oceanic fisheries. If it is to be satisfied, it will be by expanding fish farming, which will further intensify the pressure on land resources. Once fish are put in ponds or cages, they have to be fed. (See Chapter 7.)

Forests Shrinking

At the beginning of the twentieth century, the earth's forested area was estimated at 5 billion hectares. Since then it has shrunk to 2.9 billion hectares—an area roughly double the world's cropland area. The remaining forests are rather evenly divided between tropical and subtropical forests in developing countries and temperate/boreal forests in industrial countries.[23]

Deforestation is caused by the growing demand for forest products and the growing conversion of forested land to agricultural uses. This forest loss is concentrated in developing countries. From 1990 to 1995, the loss in these nations averaged 13 million hectares a year, an area roughly the size of Kansas. Overall, this means that the developing world is losing 6.5 percent of its forests per decade. The industrial world is actually gaining up to an estimated 3.6 million hectares of forestland each year, principally from abandoned cropland that is returning to forests on its own, as in Russia, and the spread of commercial forestry plantations.[24]

Unfortunately, even these official FAO data do not reflect the gravity of the situation. For example, tropical forests that are clearcut or burned off rarely recover. They simply become wasteland or at best scrub forest, but they are still included in the official forestry numbers if they are not included in another land use category such as cropland or building construction. The World Resources Institute's Forest Frontiers Initiative issued a report in 1997 on the status of the world's forests. They note that "hidden behind such familiar statistics is an equally sobering reality. Of the forests

that do remain standing, the vast majority are no more than small or highly disturbed pieces of the fully functioning ecosystems they once were." The report notes that only 40 percent of the world's remaining forest cover can be classified as frontier forest, which they define as "large, intact, natural forest systems relatively undisturbed and big enough to maintain all of their biodiversity, including viable populations of the wide-ranging species associated with each type."[25]

Use of each of the principal forest products—firewood, paper, and lumber—is expanding. Of the 3.28 billion cubic meters of wood harvested worldwide in 1999, over half was used for fuel. In developing countries, the share was far higher, nearly four fifths of the total. In industrial countries, roughly 14 percent of the wood harvested was used for fuel, much of it the waste wood used by pulp and paper mills to generate electricity and to provide process heat. Using the bark and small branches for fuel, some paper mills are energy self-sufficient.[26]

Deforestation to satisfy fuelwood demand is extensive in the Sahelian zone of Africa and the Indian subcontinent. As urban firewood demand surpasses the sustainable yield of nearby forests, the woods slowly retreat from the city in an ever larger circle, a process clearly visible from satellite photographs taken over time. As the circles enlarge, the transport costs of firewood increase, triggering the development of an industry in charcoal, a more concentrated form of energy with lower transportation costs.[27]

Logging also takes a heavy toll, as is evident in countries in Africa, the Caribbean, and the Pacific. In almost all cases, logging is done by foreign corporations more interested in maximizing the harvest of forest products on a one-time basis than in managing forests to maximize sustainable yield in perpetuity. Once a country's forests are totally clearcut, companies typically move on, leaving only devastation behind.[28]

Another loss of forests comes from clearing land for agriculture and plantations, usually by burning, a loss that is concentrated in the Brazilian Amazon and more recently in Borneo and Sumatra in Indonesia. After losing 97 percent of the Atlantic rainforest, Brazil is now destroying its Amazon rainforest. This huge forest, roughly the size of Europe, was largely intact until 1970. Since then, 14 percent of Brazil's rainforest has been lost. In 1999 alone, 17,000 square kilometers were deforested.[29]

The progressive loss of forest cover has both economic and environmental consequences. Economically, the countries that have lost their exportable supplies of forest products, such as Nigeria and the Philippines, are now net importers of forest products. Also lost are the jobs and income that their forest industries once provided.[30]

The environmental effects of deforestation are becoming all too visible. Scores of countries are suffering from disastrous flooding as a result of deforestation. In 1998, the Yangtze River basin, which has lost 85 percent of its original tree cover, experienced some of the worst flooding in its history. In 2000, Mozambique was partially inundated as the Limpopo overflooded its banks, taking thousands of lives and destroying homes and crops on an unprecedented scale. The Limpopo river basin, which has lost 99 percent of its original tree cover, will likely face many more such floods.[31]

While deforestation accelerates the flow of water back to the ocean, it also reduces the airborne movement of water to the interior. The world's forests are in effect conduits or systems for transporting water inland. Eneas Salati and Peter Vose, two Brazilian scientists writing in *Science*, observed that as moisture-laden air from the Atlantic moves westward across the Amazon toward the Andes, it carries moisture inland. As the air cools and this moisture is converted into rainfall, it waters the rainforest below. In a healthy rainforest, roughly one fourth of the rainfall runs off into rivers and back to the Atlantic Ocean. The other three fourths evaporates and is carried further inland, where the process is again repeated. It is this water cycling capacity of rainforests that brings water inland to the Amazon's vast western reaches.[32]

If the rainforest is burned off and planted to grass for cattle raising, then the cycling of rainfall is dramatically altered—three fourths of the rainfall runs off and returns to the sea the first time it falls, leaving little to be carried inland. As more and more of the Amazon is cleared for cattle ranching or farming or is degraded by loggers, the capacity of the rainforest to carry water inland diminishes. As a result, the western part of the forest begins to dry out, changing it into a dryland forest or even a savanna.[33]

The burning and cutting of the Amazonian rainforest could also affect agriculture in regions to the south. As the air masses moving inland from the Atlantic reach the Andes, they turn southward, carrying moisture with them. It is this moisture that provides part

of the rainfall in the agricultural regions of southwestern Brazil, Paraguay, and northern Argentina. As the deforestation of the Amazon progresses, the flow of moisture to these farming areas will likely diminish. Efforts to boost farm output by clearing land in the eastern Amazon basin could reduce farm output in southwestern Brazil.[34]

A similar situation may be developing in Africa, where deforestation and land clearing are proceeding rapidly as the demand on firewood mounts and as logging firms clear large tracts of virgin forests. As the forest area shrinks, the amount of rainfall reaching the interior of Africa is diminishing. A comparable trend is unfolding in China. Wang Hongchang, a Fellow of the Chinese Academy of Social Sciences, cites deforestation in the southern and eastern provinces of China as a key reason for the rainfall decline in the country's northwest, the area where the dust bowl is forming.[35]

A number of countries now have total or partial bans on logging in primary forests, including Cambodia, China, India, New Zealand, the Philippines, Sri Lanka, Thailand, and Viet Nam. Additionally, about 3 million square kilometers, accounting for roughly 9 percent of the earth's remaining forest area, are set aside as parks or nature preserves or for other conservation reasons. In some cases, the forests that are set aside are carefully protected, but all too often these "paper parks" exist only in theory and in the meaningless laws that set them up.[36]

Rangelands Deteriorating

One tenth of the earth's land surface is cropland, but an area twice this size is rangeland—land that is too dry, too steeply sloping, or too infertile to sustain crop production. This area—one fifth of the earth's land surface, most of it semiarid—supports the world's 3.3 billion cattle, sheep, and goats. (See Table 3–1.) These livestock are ruminants, animals with complex digestive systems that enable them to convert roughage into beef, mutton, and milk.[37]

An estimated 180 million people worldwide make their living as pastoralists tending cattle, sheep, and goats. Many countries in Africa depend heavily on their livestock economies for food and employment. The same is true for large populations in the Middle East, Central Asia (including Mongolia), northwest China, and much of India. India, which has the world's largest concentration of ruminants, depends on cattle and water buffalo not only for

Table 3–1. *Domesticated Ruminants by Country, 2000*

Country	Cattle and Buffalo	Sheep and Goats
	(million head)	
Argentina	55	17
Australia	26	117
Bangladesh	24	35
Brazil	169	31
China	127	279
Ethiopia	35	39
France	20	11
India	313	181
Mexico	30	16
Nigeria	20	45
Pakistan	45	72
Russia	28	16
United Kingdom	11	45
United States	98	9
Other	509	868
World	1,510	1,780

Source: FAO, *FAOSTAT Statistics* Database, <apps.fao.org>, updated 2 May 2001.

milk but also for draft power and fuel.[38]

In other parts of the world, rangelands are exploited by large-scale commercial ranching. Australia, whose land mass is dominated by rangeland, has one of the world's largest sheep flocks of 117 million sheep—6 for each Australian. Grass-based livestock economies also predominate in Argentina, Brazil, Mexico, and Uruguay. And in the Great Plains of North America, lands that are not suited to growing wheat are devoted to grazing cattle.[39]

Although public attention often focuses on the role of feedlots in beef production, the world's beef and mutton are produced largely on rangeland. The share of the world's cattle, sheep, and goats in feedlots at any time is a tiny fraction of the vast numbers feeding on grass. Even in the United States, which has most of the world's feedlots, the typical steer is in a feedlot for only a matter of months. If rangelands deteriorate, so too will this forage-based segment of the world's livestock economy.

Beef and mutton tend to dominate meat consumption where grazing land is abundant relative to population size. Among the countries with high beef consumption per person are Argentina, with 69 kilograms per year (152 pounds); the United States, with 45 kilograms; Brazil, 39 kilograms; and Australia, 36 kilograms. In some countries with extensive grazing land, mutton looms large in the diet, as in New Zealand with 25 kilograms, Australia 14 kilograms, and Kazakhstan 7 kilograms.[40]

These same ruminants that are uniquely efficient at converting roughage into meat and milk for human consumption are also a source of leather and wool. The world's leather goods and woolen industries, the livelihood for millions, depend on rangelands for their raw materials.

Worldwide, almost half of all grasslands are lightly to moderately degraded and 5 percent are severely degraded. The excessive pressure on grasslands, not unlike that on oceanic fisheries, afflicts industrial and developing countries alike. A survey of the U.S. public grazing lands managed by the Bureau of Land Management in 2000, for example, showed that only 36 percent of native public rangelands have forage that is in good or excellent condition, with most of the remainder of fair or poor quality.[41]

Although the data for grassland degradation are sparse, the problem is highly visible throughout Africa, where livestock numbers have tracked the growth in human numbers. In 1950, 238 million Africans relied on 273 million livestock. By 2000, there were 794 million people and 680 million livestock.[42]

In this continent where grain is scarce, 230 million cattle, 241 million sheep, and 209 million goats are supported almost entirely by grazing and browsing. The number of livestock, a cornerstone of the economy everywhere except in the tsetse-fly belt (roughly the western Congo Basin), often exceeds grassland carrying capacity by half or more. A study that charted the mounting pressures on grasslands in nine southern African countries found that the capacity to sustain livestock is diminishing.[43]

Iran—one of the most populous countries in the Middle East, with 70 million people—illustrates the pressures facing that region. With more than 8 million cattle and 81 million sheep and goats—the source of wool for its fabled rug-making industry—Iran is faced with the deterioration of its rangelands because of overstocking. In a country where the sheep and goats outnumber humans, mutton

consumption looms large in the diet. However, with rangelands now being pushed to their limits and beyond, the current livestock population may not be sustainable.[44]

China faces similarly difficult challenges. In northwestern China, the buildup in livestock since the economic reforms in 1978 is destroying vast areas of grassland. Since then, livestock numbers have increased dramatically. In Gonge County, for example, in eastern Qinghai Province, the number of sheep that the local grasslands can support is estimated at 3.7 million, but by the end of 1998, the region's flock had reached 5.5 million—far beyond its carrying capacity. The result is fast-deteriorating grassland, desertification, and in some locations the creation of sand dunes. Erik Eckholm, writing in the *New York Times*, reports that "the rising sands are part of a new desert forming here on the eastern edge of the Qinghai-Tibet Plateau, a legendary stretch once known for grasses reaching as high as a horse's belly and home for centuries to ethnic Tibetan herders."[45]

Fodder needs of livestock in nearly all developing countries now exceed the sustainable yield of rangelands and other forage resources. In India, the demand for fodder in 2000 was estimated at 700 million tons, while the sustainable supply totaled just 540 million tons. The National Land Use and Wastelands Development Council there reports that in states with the most serious land degradation, such as Rajasthan and Karnataka, fodder supplies satisfy only 50–80 percent of needs, leaving large numbers of emaciated, unproductive cattle. [46]

After mid-century, world beef and mutton production expanded much faster than population, climbing from 9 kilograms per person in 1950 to 13 kilograms in 1972. (See Figure 3–1.) Since then, however, the growth in world beef and mutton production has fallen behind that of population, dropping the per capita supply to 11 kilograms, a decline of about one fifth.[47]

Land degradation from overgrazing is taking a heavy economic toll in the form of lost livestock productivity. In the early stages of overgrazing, the costs show up as lower land productivity. But if the process continues, it destroys vegetation, leading to the erosion of soil and the eventual creation of wasteland. A U.N. assessment of the earth's dryland regions showed that livestock production lost from rangeland degradation exceeded $23 billion in 1990. (See Table 3–2.)[48]

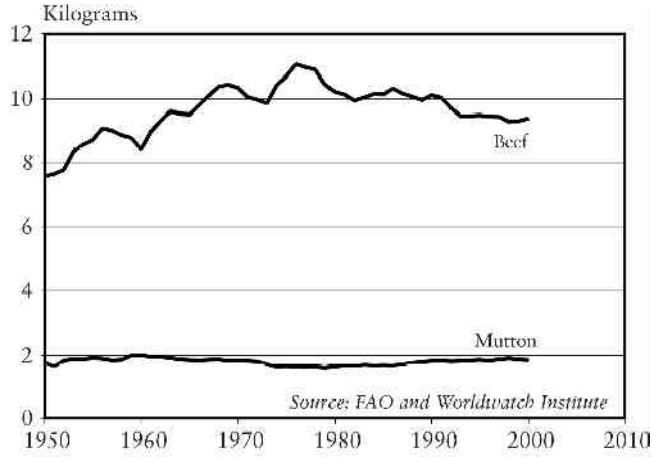

Figure 3–1. *World Beef and Mutton Production Per Person, 1950–2000*

In Africa, the annual loss of rangeland productivity is estimated at $7 billion, more than the gross domestic product of Ethiopia. In Asia, livestock losses from rangeland degradation total over $8 billion. Together, Africa and Asia account for two thirds of the global loss.[49]

With most rangeland now being grazed at capacity or beyond, the prospect for substantial future gains in beef and mutton production from rangelands is not good. And given the inefficient conversion of grain to meat by cattle, substantial further gains in beef and mutton production may be possible only by feeding more crop residues. (See Chapter 7.)

Soils Eroding

After the earth was created, soil formed slowly over time from the weathering of rocks. It was this soil that supported early plant life on land. As plant life spread, the plants protected the soil from wind and water erosion, permitting it to accumulate and to support even more plant life. This symbiotic relationship facilitated an accumulation of topsoil until it could support a rich diversity not only of plants, but also of the animal life that depends on plants.

The thin mantle of topsoil, measured in inches over most of the earth, is the foundation of civilization. When earlier civilizations lost their productive topsoil from mismanagement and erosion, they

Table 3–2. *Livestock Production Loss from Land Degradation in Dryland Regions, 1990*

Continent	Production Loss (billion dollars)
Africa	7.0
Asia	8.3
Australia	2.5
Europe	0.6
North America	2.9
South America	2.1
Total[1]	23.2

[1] Column does not add up to total due to rounding.
Source: See endnote 48.

crumbled as their food supply shrank. With an estimated 36 percent of the world's cropland now losing topsoil at a rate that is undermining its productivity, our food security is also at risk if this trend continues.[50]

As pressures to expand food production have climbed, farmers have been forced into marginal areas, plowing land that is too dry or too steeply sloping to sustain cultivation. At some point probably within the last century, the long-term accumulation of topsoil was reversed as erosion losses surpassed new soil formation, leading to a gradual depletion of this basic natural capital.

The United States, the world's breadbasket, has undergone two periods of extensive overplowing, each of which led to heavy losses of topsoil. The first occurred in the early 1930s when a severe multiyear drought led to extensive wind erosion in the southern Great Plains. The resulting environmental devastation not only gave the era its name, the Dust Bowl, but it triggered one of the largest internal migrations in U.S. history as droves of people left the southern Great Plains and headed west for California.[51]

After new agricultural practices were adopted in response to the Dust Bowl, such as planting windbreaks and strip-cropping land, with alternate-year fallowing, the soil was stabilized. But as demand for food began to climb rapidly after mid-century, and as grain prices reached record highs during the 1970s, farmers again began plowing from "fencerow to fencerow"—planting everything

in sight. By 1982, the United States was losing annually an estimated total of 3.08 billion tons of topsoil from its cropland.[52]

In contrast to the Dust Bowl, when wind erosion in the Great Plains was the problem, this time it was mostly water erosion in the Corn Belt. In states such as Iowa, with its rolling farmland, farmers were losing almost 20 tons of topsoil per hectare each year from water erosion. A dozen U.S. studies analyzing the effect of erosion on land productivity found that losing an inch of topsoil reduced corn and wheat yields an average of 6 percent. With nature needing centuries to form an inch of topsoil, current losses are irreversible if time horizons are measured on a human time-scale.[53]

One consequence of overplowing is that countries eventually have to pull back and reduce the harvested area. Some have done this through carefully designed programs to convert highly erodible cropland back into grassland or forests. For example, the U.S. Conservation Reserve Program (CRP) launched in 1985 was designed to simultaneously control surplus production and conserve soil by retiring the most erodible land. Initiated and supported by environmental groups, the program encouraged farmers to take their highly erodible land out of production by providing government payments under 10-year contracts to plant the land in grass or trees.[54]

Within five years, U.S. farmers had converted nearly 15 million hectares of cropland, roughly 10 percent of the national total, to grassland. This reduced excessive soil erosion nationwide by some 40 percent, helping to enhance food security for the entire world. The nonmarket benefits from soil erosion reduction and the provision of habitat by the CRP between 1985 and 2000 are estimated to exceed $1.4 billion.[55]

The Soviet Union overexpanded its plowing with the Virgin Lands Project between 1954 and 1960. In an effort to boost farm output and become an agricultural superpower, the Soviets plowed up vast areas of grassland in Central Asia, an effort centered in Kazakhstan. During this period, the increase in wheat area in Kazakhstan was equal to the entire wheat area of Canada and Australia combined.[56]

Unfortunately, not all of this land could sustain cultivation. Much of the wheatland of Kazakhstan, a semiarid country, has eroded to the point where it can no longer support cropping. After the grain area reached 25 million hectares by 1960, it held there until 1984

or so, when it started shrinking as productivity fell and the less productive land was abandoned. By 2001, it had dropped to 12 million hectares. (See Figure 3–2.) Although this loss may have surprised the political leaders in Moscow who engineered the expansion in the 1950s, it did not surprise the soil scientists at the Institute of Soil Management in Alma Alta, who pointed out in 1994 that grain cultivation could be sustained on only half the area originally plowed. Even those estimates may prove to be overly optimistic.[57]

Whether topsoil loss, declining yields, and the abandonment of cropland in Kazakhstan can be arrested remains to be seen. Even the grainland still being farmed yields less than 1 ton of wheat per hectare—a fraction of the 7 tons per hectare in France, the leading wheat producer in Western Europe.[58]

If soil erosion proceeds too far, it can convert land to desert, becoming wasteland. At an intermediate stage of degradation, it can be returned to grassland, as in Kazakhstan, retaining some productive value. If the intervention comes early enough in the decline cycle, the land can be saved by managing it responsibly, as was the case during the Dust Bowl period. Or the land can be systematically retired and converted to grassland or woodland. Yet for many developing countries, where populations have doubled or even tripled over the last half-century, this is not always an option.

In the majority of developing countries, the growing demand

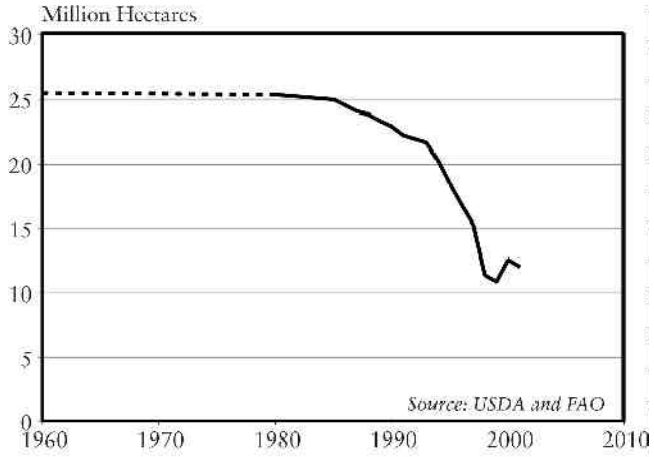

Figure 3–2. *Total Grain Harvested Area for Kazakhstan, 1960–2001*

for food has forced agriculture onto marginal lands. In China, for instance, a doubling of population since 1950 combined with record rises in income since 1980 have nearly tripled the demand for grain.[59]

China's loss of cropland to the construction of factories, roads, and expanding cities, particularly in the prosperous coastal provinces, led to mounting concern in Beijing about the country's shrinking cropland area. The result was an attempt to offset these losses by plowing more land in the semiarid northwest. But the newly plowed land, much less productive, was highly vulnerable to wind erosion.[60]

As described at the beginning of this chapter, in recent years dust storms in China have become more frequent and more intense, often covering cities in the northeast with layers of dust. In May 2000, the *China Daily* reported, "Disastrous sand storms that hit several major cities recently in North China have alarmed the nation about the devastating consequences of the development strategy that turned a blind eye on the environment." The desertification now under way in northwest China aroused public concern as "dust-laden blasts began to bury villages, blow into cities, and suffocate residents."[61]

These new reports, coupled with scientific studies, indicate that a dust bowl is forming in northern China. The April 2001 dust storm mentioned earlier was one of the largest ever recorded. U.S. scientists in Colorado measured the dust in this storm above them in Boulder at altitudes up to 10,700 meters (35,000 feet). China is losing millions of tons of topsoil, a depletion of its natural capital that it can ill afford.[62]

In Africa, population growth and the degradation of cropland are also on a collision course. Rattan Lal, an internationally noted agronomist at Ohio State University's School of Natural Resources, has made the first estimate of yield losses due to soil erosion for the continent. Lal concluded that soil erosion and other forms of land degradation have reduced Africa's grain harvest by 8 million tons, or roughly 8 percent. Further, he expects the loss to climb to 16 million tons by 2020 if soil erosion continues unabated.[63]

Among the countries experiencing unusually heavy soil losses are Nigeria, Rwanda, and Zimbabwe. Nigeria, Africa's most populous nation, is suffering from extreme gully erosion. Lal reports gullies 5–10 meters deep and 10–100 meters wide. In January 2001, Alhaji Sanni Daura, Nigeria's Minister of Environment, announced

that the country was losing some 500 square kilometers of cropland to desertification each year. Daura is concerned that unless this desert encroachment can be reversed, Nigeria may soon face severe food shortages.[64]

On the northern edge of the Sahara, Algeria is also faced with the desertification of cropland. In December 2000, the agriculture ministry announced a four-year plan to halt the advancing desertification that they fear will soon threaten the fertile northern areas of the country. The plan is to convert the southernmost 20 percent of its grainland into tree crops, including fruit and olive orchards and vineyards. The government hopes that this barrier of permanent vegetation will halt the northward march of the Sahara. Out of desperation, Algeria, a country already dependent on imports for 40 percent of its grain, is willing to convert one fifth of its grain-producing land to tree crops in an attempt to protect the remaining four fifths.[65]

In East Africa, governments are facing a similar situation. Countries such as Ethiopia, Kenya, and Somalia are experiencing land degradation and cropland abandonment. Kenya's 1950 population of 6 million has increased to 31 million, putting unsustainable pressure on local forests, rangelands, and croplands. During the severe drought of 2000, the Masai, in an act of desperation, drove their cattle into Nairobi to feed on the grass in well-watered parks and residential lawns.[66]

The failure of Africa's governments to address the soil erosion threat effectively is depleting Africa's most essential natural capital—its soil. The next generation of farmers in Africa must try to feed not the 800 million people of today, but the projected 2 billion in the year 2025—and with far less topsoil.[67]

In Mexico, many of the 900,000 migrants who leave rural communities in arid and semiarid regions of the country each year are doing so because of desertification. Some of these environmental refugees end up in Mexican cities, others cross the northern border into the United States. U.S. analysts estimate that Mexico is forced to abandon 1,036 square kilometers (400 square miles) of farmland to desertification each year.[68]

The World Bank, citing studies for Costa Rica, Malawi, Mali, and Mexico, concludes that the gradual losses of agricultural productivity from soil erosion now translate into annual losses in farm output equal to 0.5–1.5 percent of these countries' gross domestic

products. The toll of soil erosion on the earth's productivity can be seen in the abandoned villages in Ethiopia, where there is not enough soil left to support even subsistence-level agriculture. And in the former Soviet Union, land degradation, mostly from erosion, helped convert some 20 percent of the land in grain in 1977 either to soil-conserving forage crops, to alternate-year fallowing, or, where there was no effort to save the soil, to forest or wasteland by 1993.[69]

Unfortunately, many countries have not taken the initiative to reduce soil erosion and are paying a high price. For example, lost productivity on Africa's rain-fed cropland, virtually all from soil erosion, has reduced the annual harvest by an estimated $1.9 billion.[70]

The challenge is to arrest the excessive loss of topsoil on all land everywhere, reducing it to or below the level of new soil formation. The world cannot afford this loss of natural capital. If we cannot preserve the foundation of civilization, we cannot preserve civilization itself.

Species Disappearing

The archeological record shows five great extinctions since life began, each representing an evolutionary setback, a wholesale impoverishment of life on the earth. The last of these mass extinctions occurred some 65 million years ago, most likely when an asteroid collided with the earth, spewing vast amounts of dust and debris into the atmosphere. The resultant abrupt cooling obliterated the dinosaurs and at least one fifth of all other extant life forms.[71]

We are now in the early stage of the sixth great extinction. Unlike previous ones, which were caused by natural phenomena, this one is of human origin. For the first time in the earth's long history, one species has reached the point where it can eradicate much of life.

As various life forms disappear, they alter the earth's ecosystem, diminishing the services provided by nature, such as pollination, seed dispersal, insect control, and nutrient cycling. This loss of species is weakening the web of life, and if it continues it could tear huge gaps in its fabric, leading to irreversible and potentially unpredictable changes in the earth's ecosystem.

Species of all kinds are threatened by habitat destruction, principally through the loss of tropical rainforests. As we burn off the

Amazon rainforest, we are burning one of the great genetic storehouses, in effect one of the great libraries of genetic information. Our descendents may one day view the wholesale burning of this repository of genetic information much as we view the burning of the library in Alexandria in 48 BC.

Habitat alteration from rising temperatures, chemical pollution, or the introduction of exotic species can also decimate both plant and animal species. As human population grows, the number of species with which we share the planet shrinks. We cannot separate our fate from that of all life on the earth. If the rich diversity of life that we inherited is continually impoverished, eventually we will be as well.[72]

The share of birds, mammals, and fish that are vulnerable or in immediate danger of extinction is now measured in double digits: 12 percent of the world's nearly 10,000 bird species; 24 percent of the world's 4,763 mammal species; and an estimated 30 percent of all 25,000 fish species.[73]

When the World Conservation Union–IUCN released its newest *Red List of Threatened Species* in 2000, it showed an increase in the "critically endangered" in all categories. For example, the number of critically endangered primates rose from 13 in 1996 to 19 in 2000. The number of freshwater species of turtles in this category, many of them in strong demand in Asia for food and for medicinal uses, increased from 10 to 24. For birds overall, the number in the critically endangered category went from 168 in 1996 to 182 in 2000. Like many other trends of environmental decline, this one, too, is accelerating.[74]

Among mammals, the 600 known species of primates other than humans are most at risk. IUCN reports that nearly half of these species are threatened with extinction. Some 79 of the world's primate species live in Brazil, where habitat destruction poses a particular threat. Hunting, too, endangers many primate species. It is a threat principally in West and Central Africa, where the deteriorating food situation is creating a lively market for "bushmeat."[75]

The bonobos of West Africa, a smaller version of the chimpanzees of East Africa, may be our closest living relative both genetically and in terms of social behavior. But this is not saving them from the bushmeat trade or the destruction of their habitat by loggers. Concentrated in the dense forest of the Democratic Republic of the Congo, their numbers fell from an estimated 100,000 in

1980 to fewer than 10,000 by 1990. Today there are only 3,000 left. In less than one generation, 97 percent of the bonobos have disappeared.[76]

Birds, because of their visibility, are a useful indicator of the diversity of life. Of the 9,946 known bird species, roughly 70 percent are declining in number. Of these, an estimated 1,183 species are in imminent danger of extinction. Habitat loss and degradation affect 85 percent of all threatened bird species. For example, 61 bird species have become locally extinct with the extensive loss of lowland rainforest in Singapore. Some once-abundant species may have already dwindled to the point of no return. The great bustard, once widespread in Pakistan and surrounding countries, is being hunted to extinction. Ten of the world's 17 species of penguins are threatened or endangered, potential victims of global warming.[77]

The threat to fish may be the greatest of all, with nearly one third of all species—freshwater and saltwater—now facing possible extinction. Worldwide, the principal causes of this loss are habitat degradation in the form of pollution and the excessive extraction of water from rivers and other freshwater ecosystems. An estimated 37 percent of the fish species that inhabit the lakes and streams of North America are either extinct or in jeopardy. Ten North American freshwater fish species have disappeared during the last decade. In semiarid regions of Mexico, 68 percent of native and endemic fish species have disappeared. The situation may be even worse in Europe, where some 80 species of freshwater fish out of a total of 193 are threatened, endangered, or of special concern. Two thirds of the 94 fish species in South Africa need special protection to avoid extinction.[78]

Threatened species include both little known ones and those that are well known and highly valued. The harvest of the Caspian Sea sturgeon, for example, source of the world's most prized caviar, has fallen from 22,000 tons per year in the late 1970s to 1,100 tons in the late 1990s. Overfishing, much of it illegal, is responsible.[79]

Another indicator of the earth's environmental deterioration is the decline in various types of amphibians—frogs, toads, and salamanders. Widespread evidence that amphibian populations were disappearing initially surfaced at the first World Congress of Herpetology in Canterbury, England, in 1989. It was at this confer-

ence that scientists first realized that the seemingly isolated disappearances of amphibian populations were actually a worldwide phenomenon. Among the apparent contributing factors are the clearcutting of forests, the loss of wetlands, the introduction of alien species, changes in climate, increased ultraviolet radiation, acid rain, and pollution from both agriculture and industry. Spending their lives in both aquatic and terrestrial environments, amphibians are affected by changes in each, making them an unusually sensitive barometer of the earth's changing physical condition.[80]

The leatherback turtle, one of the most ancient animal species, and one that can reach a weight of 360 kilograms (800 pounds), is fast disappearing. Its numbers have dropped from 115,000 in 1982 to 34,500 in 1996. At the Playa Grande nesting colony on Costa Rica's west coast, the number of nesting females dropped from 1,367 in 1989 to 117 in 1999. James Spotila and colleagues, writing in *Nature*, warn that "if these turtles are to be saved, immediate action is needed to minimize mortality through fishing and to maximize hatchling production."[81]

One of the newer threats to species, and one that is commonly underestimated, is the introduction of alien species, which can alter local habitats and communities, driving native species to extinction. For example, non-native species are a key reason why 30 percent of the threatened bird species are on the IUCN *Red List*. For plants, alien species are implicated in 15 percent of all the listings. One consequence of globalization with its expanding international travel and commerce is that more and more species are being accidentally or intentionally brought into new areas where they have no natural predators.[82]

Efforts to save wildlife traditionally have centered on the creation of parks or wildlife reserves. Unfortunately, this approach may now be of limited value because of the nature of the principal threats to biological diversity. If we cannot stabilize population and climate, there is not an ecosystem on earth that we can save. To optimize resource use, this would argue for shifting some of the relatively abundant funds for parkland acquisition into efforts to stabilize population and climate.

The current species extinction rate is at least 1,000 times higher than the background rate, yet no one knows how many plant and animal species there are today, much less how many there were a half-century ago, when the explosion in human economic activity

began. Current estimates range from 6 million species up to 20 million, with the best working estimates falling between 13 million and 14 million. We can measure losses where we have a complete inventory of species, as with birds, but with insects, where the species number in the millions, only a fraction of the species have been identified, described, and cataloged.[83]

Synergies and Surprises

One concern of environmental scientists is that some trends of environmental degradation will reinforce each other, accelerating the process. Chris Bright of Worldwatch Institute has analyzed several of these synergistic relationships among environmental trends, both local and global. One such concern is with ice melting. When land is covered with ice and snow, much of the sunlight reaching the earth's surface is simply bounced back into space by the high reflectivity of the surface. Once the snow and ice melts, the soil or the water beneath absorbs much of the energy in the sunlight, raising temperatures. The higher temperature leads to more melting, and the process begins to feed on itself in what scientists call a positive feedback loop.[84]

This is of particular concern in the Arctic Sea, where ice is melting, shrinking the reflective area. (See Chapter 2.) The synergistic relationship between rising temperatures and reduced reflectivity may now have reached the point of no return in the Arctic, suggesting a future when Arctic sea ice may disappear entirely during the summer months. This rise in temperature in the polar region may also help explain why the Greenland ice sheet is beginning to melt.[85]

Another set of synergies is threatening the earth's forests by fire. Intact, healthy rainforests do not burn, but forests weakened by logging or slash-and-burn farming become vulnerable to fire. The more they burn, the more vulnerable they become. The process, which feeds on itself, reinforces the global warming trend. As higher temperatures due to climate change lead to the drying out of forests and more burning, more carbon is emitted into the atmosphere. Rising atmospheric carbon dioxide levels accelerate the process of global warming. The trends of rising temperatures and burning forests begin to reinforce each other.[86]

One consequence of many interacting changes is that they can lead to developments that surprise even the scientific community.

One such event came in August 2000, as described in Chapter 2, when the icebreaker cruise ship discovered open water at the North Pole. Yet another recent surprise is the dieoff of coral reefs. Again, the reasons for the coral dieoff are complex, but a rise in surface water temperature may be responsible. What is surprising is that a temperature rise in sea surface water of less than 1 degree Celsius can lead to reef deaths. If the reefs continue to die, oceanic ecosystems will be altered, directly affecting the fisheries that depend on the coral reefs as nursery grounds.[87]

These are but a few of the surprises and synergies that have been encountered in recent years. No one knows how many the new century will bring. And unfortunately, synergistic trends such as those just described are often irreversible. As Chris Bright observes, "Nature has no reset buttons."[88]

II

The New Economy