8

Raising Land Productivity

From the beginning of agriculture until 1950 or so, growth in world food production came almost entirely from expanding the cultivated area. Rises in land productivity were negligible, scarcely perceptible from one generation to the next. Then as the frontiers of agricultural settlement disappeared, the world began systematically to raise land productivity. Between 1950 and 2000, grainland productivity climbed by 160 percent while the area planted in grain expanded only 14 percent.[1]

This extraordinary rise in productivity, combined with the modest expansion of cultivated area, enabled farmers to triple the grain harvest over the last half-century. At the same time, the growing demand for animal protein was being satisfied largely by a quintupling of the world fish catch to 95 million tons and a doubling of world beef and mutton production, largely from rangelands. These gains not only supported a growth in population from 2.5 billion to 6.1 billion, they also raised food consumption per person, shrinking the share who were hungry.[2]

As we look ahead at the next half-century, we face a demand situation that is similar in that the world is facing a projected increase of nearly 3 billion people, only slightly less than during the last half-century, but now virtually all the increase is coming in developing countries. In 1950, most of the world wanted to move up the food chain, eating more livestock products. That is also true today, but instead of 2 billion wanting to move up the food chain, there are now close to 5 billion.[3]

With agricultural supply, however, there are sharp differences. The annual rise in land productivity, averaging 2.1 percent from 1950 to 1990, dropped to 1 percent from 1990 to 2002. In addition, oceanic fisheries and rangelands have been pushed to their limits and beyond, which means we cannot expect much, if any, additional output from either system. Future gains in animal protein production will have to come largely from feeding grain to animals, whether they be livestock, poultry, or fish. And this means more demands on the world's croplands.[4]

At the center of the tripling of world grain production during the last century were high-yielding varieties, the dwarf wheats and rices developed originally in Japan and hybrid corn from the United States. Under favorable conditions, these varieties could double, triple, even quadruple the yields of traditional varieties. But there are no new varieties in the pipeline that can lead to similar quantum jumps in yields. Nearly two decades have passed since the first genetically modified crop varieties were released, yet biotechnologists have yet to produce a single variety of wheat, rice, or corn that can dramatically raise yields. Nor does it seem likely that they will, simply because plant breeders, using conventional breeding techniques, have already taken most of the obvious measures to get the big jumps in yields.[5]

Helping to realize the genetic potential of the new high-yield varieties was the growth in irrigation, which expanded from 94 million hectares in 1950 to 272 million in 2000, raising the share of the world's grain harvest

from irrigated land to 40 percent. Now growth in the irrigated area is slowing as many countries lose irrigation water from aquifer depletion and its diversion to cities.[6]

As high-yielding varieties spread and irrigated area expanded, fertilizer use climbed from 14 million tons in 1950 to 137 million tons in 2000—a tenfold gain. While irrigation was removing the moisture constraints on crop yields, fertilizer was removing nutrient constraints. Then diminishing returns set in and the growth in fertilizer use slowed markedly. In the United States, Western Europe, and Japan, use has not increased for more than a decade. It may also now be leveling off in China, the world's largest user of fertilizer. There are still many countries that can profitably increase fertilizer use, including India and Brazil. But for much of the world, applying more fertilizer now has little effect on yields.[7]

Looking back, the greatest progress in eradicating hunger came while grain production per person was climbing from 251 kilograms in 1950 to 344 kilograms in 1984. During these 34 years, the rising tide of food production was reducing hunger throughout the world. After 1984, however, growth in the grain harvest slowed, falling behind that of population. By 2002, it had fallen to 290 kilograms per person, a decline of 18 percent from the peak in 1984.[8]

Rethinking Land Productivity

After climbing from 1.1 tons per hectare in 1950 to 2.8 tons in 2002, the world grain yield has reached a level where it is becoming more difficult to sustain a continuing rapid rise. Much of the impressive gain in yields came as scientists boosted the share of photosynthate going to seed from 20 percent in traditional varieties to over 50 percent in modern high-yielding grains, close to the theoretical limit. Efforts to raise yields further are starting to push against the physiological limits of plants. In many countries, the rise in yields is slowing and in some it is leveling off. For example, yields have not risen much in rice in Japan since 1984, in wheat in Mexico since 1980, or in wheat in the United States since 1985.[9]

This loss of momentum is worldwide. While world grainland productivity rose by just over 2 percent a year from 1950 to 1990, it averaged only 1 percent annually from 1990 to 2001. (See Table 8–1.) And in the last five years from 1997 to 2002, the annual yield gain dropped to 0.5 percent.[10]

The rise in grain yields will likely slow further during this decade. In addition to the shrinking backlog of technology to draw upon, many farmers also must deal with a loss of irrigation water, and farmers worldwide are facing the prospect of record-high temperatures—all of which could make it difficult to sustain a steady rise in land productivity.

Although the rise in yields is slowing, there are still many opportunities for increasing yields, but in most situations the potential for doing so is modest. In Africa, for example, where fertilizer use is restricted by aridity and

Table 8–1. *Gains in World Grain Yield Per Hectare, 1950–2001*

Year	Yield Per Hectare[1] (tons)	Annual Increase (percent)
1950	1.06	
1990	2.47	2.1
2001	2.79	1.0

[1]Yields for 1990 and 2001 are three-year averages.
Source: See endnote 10.

transport costs, the simultaneous planting of grain and leguminous trees is showing promise. The trees start slowly, permitting the grain crop to mature and be harvested. Then they grow to several feet in height. The leaves dropped from the trees provide nitrogen and organic matter—both sorely needed in African soils. The wood is then cut and used for fuel. This simple, locally adapted technology, developed by Pedro Sanchez, head of the International Centre for Research in Agroforestry in Nairobi, often enables farmers to double their grain yields within a matter of years as soil fertility builds.[11]

The magnitude of the challenge ahead is unmistakable. It will force us to think about both limiting the growth in demand and using the existing harvest more productively. On the demand side, achieving an acceptable balance between food and people may now depend on stabilizing world population as close to 7 billion as possible and reducing the unhealthily high level of consumption of livestock products in industrial countries. But we must also think more broadly about land productivity, considering not only the individual crop but how we can increase the number of crops harvested and how to use them better.

Multiple Cropping

In North America and Western Europe, which in the past have restricted cropped area in order to avoid surpluses, there is a potential for double cropping that has not been fully exploited. Indeed, the tripling in the world grain harvest since 1950 is due in part to impressive increases in multiple cropping in Asia. As noted in Chapter 3, some of the more common multiple cropping combinations are wheat and corn in northern China, wheat and rice in northern India, and the double or triple cropping of rice in southern China and southern India.[12]

The double cropping of winter wheat and corn in the North China Plain helped make China the world's leading grain producer. Winter wheat grown there yields close to 4 tons per hectare. Corn averages 5 tons. Together these two crops, grown in rotation, can yield 9 tons of grain per hectare per year. Double cropping of rice yields 8 tons per hectare.[13]

A generation ago in India, land in the north was devoted to producing only wheat, but with the advent of earlier maturing, high-yielding wheats and rices, it became possible to harvest the wheat in time to plant rice. This wheat/rice combination is now widely used throughout Punjab, Haryana, and parts of Uttar Pradesh. The rice yield of 2 tons per hectare and the wheat yield of 3 tons combine for 5 tons of grain per hectare, making it a key to feeding India's 1 billion people.[14]

The area that can be multiple cropped is limited by the availability of irrigation water, early-maturing varieties, and, in developing countries, enough labor to quickly harvest one crop and plant another. The loss of low-cost rural laborers through the processes of industrialization can sharply reduce multiple cropping and therefore the harvested area. In Japan, for example, the grain-harvested area in 1961 reached a peak of nearly 5 million hectares, because farmers were harvesting an average of two crops per year. As of 2002, the harvested area had dropped to 2 million hectares, partly because of cropland conversion to nonfarm uses, but mostly because of a dramatic decline in double cropping as industry pulled labor from agriculture. Even a rice-support price four times the world market price could not keep enough workers in agriculture to support extensive multiple cropping.[15]

South Korea's harvested area has shrunk by half since peaking in 1965. Taiwan's has declined nearly two thirds

since 1975. As industrialization progresses in China and India, the more prosperous regions of these countries may see similar declines in multiple cropping. In China, where incomes have quadrupled since 1980, this process already appears to be reducing production.[16]

In the United States, the lifting of planting area restrictions in 1996 opened new opportunities for multiple cropping. The most common U.S. double cropping combination is winter wheat with soybeans as a summer crop. Six percent of the soybean harvest comes from land that also produces winter wheat. One benefit of this rotation is that soybeans fix nitrogen, reducing the amount of fertilizer needed for wheat.[17]

A concerted U.S. effort to both breed earlier maturing varieties and develop cultural practices that would facilitate multiple cropping could substantially boost crop output. If China's farmers can extensively double crop wheat and corn, then U.S. farmers, at a similar latitude and with similar climate patterns, might be able to do the same if agricultural research and farm policy were reoriented in support of such an initiative.

Western Europe, with its mild winters and high-yielding wheat, might also be able to double crop more with a summer grain, such as corn, or with an oilseed crop. Elsewhere in the world, Brazil and Argentina have an extended frost-free growing season climate that supports extensive multiple cropping, often wheat or corn with soybeans.[18]

Raising Protein Efficiency

The second way to raise land productivity in a world where literally billions of people want to diversify their diets by consuming less plant starch and more animal protein is to produce animal protein more efficiently. With some 37 percent of the world grain harvest, or nearly 700 million tons, used to produce animal protein, the potential for more efficient grain use is large.[19]

World meat consumption increased from 47 million tons in 1950 to 240 million tons in 2002, more than doubling consumption per person from 17 kilograms to 40 kilograms. Consumption of milk and eggs has also risen. In every society where incomes have risen, meat consumption has too, perhaps reflecting a taste that evolved over 4 million years of hunting and gathering.[20]

As both the oceanic fish catch and the production of beef on rangelands have leveled off, the world has shifted to grain-based production of animal protein to expand output. And as the demand for animal protein climbs, the mix of protein products consumed is shifting toward those that convert grain into protein most efficiently, the lower-cost products. Health concerns have also prompted some people to shift consumption from beef and pork to poultry and fish.

The efficiency with which various animals convert grain into protein varies widely. With cattle in feedlots, it takes roughly 7 kilograms of grain to produce a 1-kilogram gain in live weight. For pork, the figure is close to 4 kilograms of grain per kilogram of weight gain, for poultry it is just over 2, and for herbivorous species of farmed fish (such as carp, tilapia, and catfish), it is less than 2. As the market shifts production to the more grain-efficient products, it raises the productivity of both land and water.[21]

Global beef production, most of which comes from rangelands, grew less than 1 percent a year from 1990 to 2002. Growth in the number of cattle feedlots was minimal. Pork production grew by 2.5 percent annually, and poultry by nearly 5 percent. (See Table 8–2.) The rapid growth in poultry production, going from 41 million tons in 1990 to 72 million tons in 2002, enabled poultry to

Table 8–2. *Annual Growth in World Animal Protein Production, by Source, 1990–2002*

Source	1990	2002	Annual Growth
	(million tons)		(percent)
Aquacultural Output[1]	13	38	10.2
Poultry	41	72	4.8
Eggs	38	58	3.6
Pork	70	94	2.5
Mutton	10	12	1.5
Oceanic Fish Catch[1]	86	91	0.5
Beef	53	58	0.8

[1]Oceanic fish catch and aquacultural output figures for 2001.
Source: See endnote 22.

eclipse beef in 1995, moving it into second place behind pork. (See Figure 8–1.) World pork production, half of it in China, overtook beef production in 1979 and has continued to widen the lead since then. World beef production, handicapped by inefficient feedlot conversion, is continuing to expand, but just barely. Indeed, within the next decade or so, fast-growing aquacultural output may overtake beef production.[22]

The big winner in the animal protein sweepstakes has been aquaculture, largely because fish are highly efficient at converting feed into protein. Aquacultural output expanded from 13 million tons in 1990 to 38 million tons in 2002, growing by more than 10 percent a year. China is the leading producer, accounting for two thirds of the global output in 2000. Its output, rather evenly divided between coastal and inland areas, is dominated by finfish (mostly carp), which are produced inland in freshwater ponds, lakes, reservoirs, and rice paddies, and by shellfish

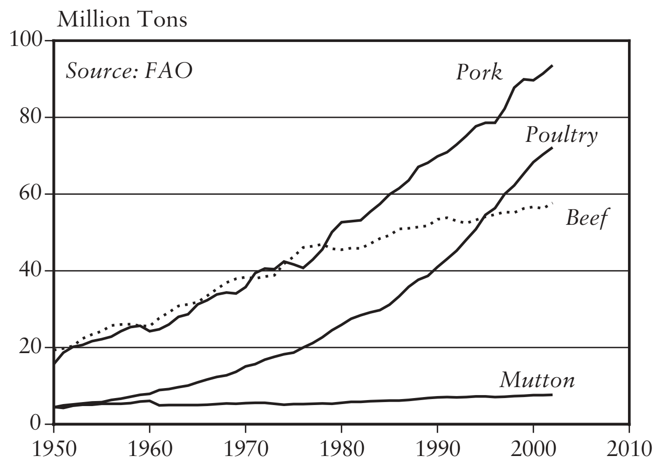

Figure 8–1. *World Meat Production by Type, 1950–2002*

(mostly oysters, clams, and mussels), which are produced in coastal regions.[23]

Over time, China has evolved a remarkably efficient fish polyculture using four types of carp that feed at different levels of the food chain, in effect emulating natural aquatic ecosystems. Silver carp and bighead carp are filter feeders, eating phytoplankton and zooplankton respectively. The grass carp, as its name implies, feeds largely on vegetation, while the common carp is a bottom feeder, living on detritus on the bottom. China's aquaculture is often integrated with agriculture, enabling farmers to use agricultural wastes, such as pig or duck manure, to fertilize ponds, thus stimulating the growth of plankton. Fish polyculture, which typically boosts pond productivity over that of monocultures by at least half, also dominates fish farming in India.[24]

As land and water become ever more scarce, China's fish farmers are feeding more grain concentrates in order

to raise pond productivity. Using this technique, China's farmers raised the annual pond yield per hectare from 2.4 tons of fish in 1990 to 4.1 tons in 1996.[25]

In the United States, catfish, which require less than 2 kilograms of feed per kilogram of live weight, is the leading aquacultural product. U.S. annual catfish production of 240,000 tons (or two pounds per person) is concentrated in four states: Mississippi, Louisiana, Alabama, and Arkansas. Mississippi, with easily 60 percent of U.S. output, is the catfish capital of the world.[26]

Public attention has focused on aquacultural operations that are environmentally disruptive, such as the farming of salmon, a carnivorous species, and shrimp. Yet these operations account for only 1.5 million tons of output. World aquaculture is dominated by shellfish and by herbivorous species—mainly carp in China and India, but also catfish in the United States and tilapia in several countries. This is where the potential for growth lies.[27]

A Second Harvest

Another initiative that can have the effect of raising land productivity involves ruminants, such as cattle, sheep, and goats. Although rangelands are being grazed to capacity and beyond, there is a large unrealized potential for feeding agricultural residues—rice straw, wheat straw, and corn stalks—to ruminants, which have a complex digestive system that enables them to convert roughage, which humans cannot digest, into animal protein. This means that a given grain crop can yield a second harvest—the meat or the milk that is produced with straw and corn stalks.

India has been uniquely successful in using cattle and water buffalo to convert crop residues into milk, expanding production from 20 million tons in 1961 to 85 million tons in 2002—a more than fourfold increase. Following a path of steady growth, milk became India's most valuable farm product in 1994, eclipsing rice. In 1997, India overtook the United States to become the world's leading milk producer. (See Figure 8–2.) Remarkably, it did so almost entirely by using farm byproducts and crop residues, avoiding the diversion of grain from human consumption to cattle.[28]

Between 1961 and 2002, India's milk production per person increased from 0.9 liters per week to 1.6 liters, or roughly a cup of milk per day. Although this is not a great deal by western standards, it is a welcome expansion in a protein-hungry country.[29]

India's milk is produced almost entirely by small farmers with one to three cows. Milk production is integrated with crop production, involving an estimated 70 million farmers for whom it is a highly valued source of supplemental income. Ownership of a few cows also means a supply of manure for fertilizer.[30]

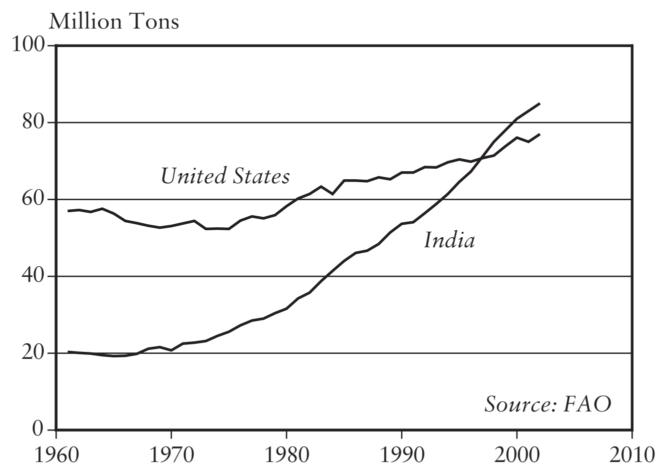

Figure 8–2. *Milk Production in India and the United States, 1961–2002*

In China, where double cropping of winter wheat and corn is common, wheat straw and corn stalks are removed from the land because there is not enough time for them to decompose before the next crop is planted. As the world's leading producer of both rice and wheat and the second largest producer of corn, China annually harvests an estimated 500 million tons of straw, corn stalks, and other crop residues. At present, with much of this either burned, simply to dispose of it, or used as fuel for cooking, there is a large potential for China to follow India's lead in using crop residues to raise protein productivity.[31]

The ammoniation of crop residues (the incorporation of nitrogen) in the roughage helps microbial flora in the rumen of the cattle and sheep to digest the roughage more completely. The use of this technology in the major crop-producing provinces of east central China—Hebei, Shandong, Henan, and Anhui—has already created a "Beef Belt." Beef output in these four provinces now dwarfs that of the grazing provinces of Inner Mongolia, Qinghai, and Xinjiang.[32]

The achievements of China in aquaculture, of India in expanding its milk production, and of other countries in producing protein more efficiently hold out hope for being able to satisfy the growing world demand for protein without clearing additional land for agriculture, assuming that we can stabilize population soon.

Saving Soil and Cropland

The world's farmers are literally losing ground on two fronts—the loss of soil from erosion and the conversion of cropland to nonfarm uses, as described in Chapter 3. Both are well-established trends that reduce agricultural output, but since both are gradual processes, they are often not given the attention that they deserve.

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, such as the planting of tree shelterbelts—rows of trees planted beside fields to slow wind and thus reduce wind erosion. Perhaps the most lasting change is strip cropping, the planting of wheat on alternate strips with fallowed land each year. This permits soil moisture to accumulate on the fallowed strips, while the planted strips reduce wind speed and hence the wind erosion on the idled strips. The key to controlling wind erosion is to keep the land covered with vegetation as much as possible and to slow wind speeds at ground level.[33]

One of the time-tested methods of dealing with water erosion is terracing to reduce runoff. On land that is less steeply sloping, as in the midwestern United States, contour farming has also worked well.[34]

Another newer, highly effective tool in the soil conservation toolkit is conservation tillage, which includes both no tillage and minimum tillage. In conventional farming, land is plowed, disked, or harrowed to prepare the seedbed, seed is drilled into the soil with a planter, and row crops are cultivated with a mechanical cultivator two or three times to control weeds. With minimum tillage, farmers simply drill seeds directly into the soil without any preparation at all. Weeds are controlled with herbicides. The only tillage is a one-time disturbance in a narrow band of soil 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.[35]

In the United States, where farmers during the 1990s were required to implement a soil conservation plan on erodible cropland to be eligible for commodity price supports, the no-till area went from 7 million hectares in 1990 to nearly 21 million hectares (51 million acres) in 2000, tripling within a decade. An additional 23 million

hectares were minimum-tilled, for a total of 44 million hectares of conservation tillage. This total included 37 percent of the corn crop, 57 percent of soybeans, and 30 percent of the wheat. Outside the United States, data for crop year 1998–99 show Brazil using conservation tillage on 11 million hectares and Argentina with 7 million hectares. Canada, at 4 million hectares, rounds out the "big four." And now no-till farming is catching on in Europe, Africa, and Asia. In addition to reducing soil losses, minimum-till and no-till practices also help retain water and reduce energy use.[36]

The U.S. method of controlling soil erosion by both converting highly erodible cropland back to grassland and adopting conservation practices to reduce erosion offers a model for the rest of the world. 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. The CRP aimed to put up to 45 million acres of highly erodible land into permanent vegetative cover under 10-year contracts. Under this program, farmers were paid to plant fragile cropland to grass or trees. The retirement of 35 million acres under the CRP, together with adoption of conservation practices on 37 percent of all cropland, reduced U.S. soil erosion from 3.1 billion tons in 1982 to 1.9 billion tons in 1997.[37]

Saving cropland is sometimes more difficult than saving the topsoil on the cropland. This is particularly the case when dealing with urban sprawl, where strong commercial forces have influence. With cropland becoming scarce, efforts to protect prime farmland from urban spread are needed everywhere. Here Japan is the model. It has successfully protected rice paddies even within the boundaries of Tokyo, thus enabling it to remain self-sufficient in rice, its staple food.[38]

In the United States, Portland, Oregon, provides another model. The state adopted boundaries to urban growth 20 years ago, requiring each community to project its growth needs for the next two decades and then, based on the results, draw an outer boundary that would accommodate that growth. Richard Moe, head of the National Trust for Historic Preservation, observes, "This has worked in Oregon because it forced development back to the city. Lot sizes are smaller. There is more density, which is made possible by mass transit. There has been a doubling of the workforce in downtown Portland over the last 20 years without one new parking lot, without one new parking space."[39]

Moe's point about Oregon draws attention to still another threat to the world's cropland, namely the automobile. In a land-hungry world, the time has come to reassess the future of the automobile and to design transportation systems that provide mobility for entire populations, not just affluent minorities, and that do this without threatening food security. When Beijing announced in 1994 that it planned to make the auto industry one of the growth sectors for the next few decades, a group of eminent scientists—many of them members of China's National Academy of Sciences—produced a white paper challenging this decision. They identified several reasons why China should not develop a car-centered transport system, but the first was that the country did not have enough land to both feed its people and accommodate the automobile.[40]

The scientists recommended that instead of building an automobile infrastructure of highways, roads, and parking lots, China should concentrate on developing state-of-the-art urban light-rail systems augmented by buses and bicycles. This would not only provide mobility for far more people than a congested auto-centered system, it would also protect cropland.[41]

There are many reasons to question the goal of building auto-centered transportation systems everywhere, including climate change, air pollution, and traffic congestion. But the loss of cropland alone is sufficient. Future food security now depends on restructuring transportation budgets—investing less in highway infrastructure and more in a land-efficient rail, bus, and bicycle infrastructure.

Restoring the Earth

The trends in soil erosion, grainland productivity, and urbanization discussed here and in Chapter 3 suggest a need to stabilize world population at a low level. The advantages of stabilizing at 7.4 billion (the low end of U.N. projections for 2050) rather than 8.9 billion (the medium projection) are clear. But it will require a substantial investment in education, health, and family planning in poor countries. Although at first glance it might appear to be costly, it will be far more costly if we fail to do so.[42]

Paralleling the effort to quickly stabilize population size is the need for the world's affluent to eat lower on the food chain and lighten the pressure on the earth's land and water resources. In a country where starchy subsistence diets prevail, as in India, annual grain consumption per person is roughly 200 kilograms, or a bit over a pound a day. At this level, nearly all the grain must be consumed directly to meet basic caloric needs, leaving little for conversion into animal protein. At the other end of the scale is the United States, where grain consumption per person exceeds 800 kilograms per year. Of this, only a small part is consumed directly in the form of bread, pastry, and breakfast cereals. The bulk is eaten indirectly as meat, milk, and eggs. Unfortunately for most Americans, consumption of fat-rich livestock products is excessive, leading to numerous health problems.[43]

The world's healthiest people are not those living at the top or the bottom of the grain consumption ladder, but rather those somewhere in the middle. In Italy, for example, grain consumption per person is less than 400 kilograms a year. Italians eat some animal protein, including meat and a variety of cheeses, but meat is more of a condiment than an entrée in Italian cuisine. Even though far less is spent on health care per person in Italy than in the United States, Italians live longer. People on the so-called Mediterranean diet live longer than either those with a diet that is heavy in fat-rich livestock products or those who get 70 percent of their calories from a single starchy staple, such as rice. If the more affluent of the earth's inhabitants who are living high on the food chain consume less animal protein, not only will they be healthier but so will the earth.[44]

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

As of 2003, for example, some 14 million hectares of U.S. cropland—roughly one tenth of the total—have been planted to grass and trees under the Conservation Reserve Program. And Algeria, trying to halt the northward advance of the Sahara Desert, is concentrating its orchards and vineyards in the southern part of the country, hoping that these perennial plantings will halt the desertification of its cropland. Only time will tell if this program, launched by Ministry of Agriculture officials in December 2000, will succeed.[45]

China may be facing the biggest challenge on the land degradation front. At the heart of its effort to halt the advance of existing deserts and the formation of new ones is a program to pay farmers in the threatened provinces to plant their cropland in trees. By 2010, 10 million hectares of grainland are to be covered with trees, representing easily one tenth of China's current grainland area.[46]

In Inner Mongolia (Nei Monggol), efforts to halt the advancing desert and to reclaim the land for productive uses initially involved planting desert shrubs to stabilize the sand dunes. And in many situations, sheep and goats are banned entirely and cattle are brought in instead. In Helin County, south of the provincial capital of Hohhot, such a strategy is yielding results. The planting of desert shrubs on abandoned cropland has now stabilized the county's first 7,000-hectare reclamation plot. Based on this success, the reclamation effort is being expanded.[47]

The Helin County strategy is centered on a shift from sheep and goats to dairy cattle, increasing the number of dairy animals from 30,000 in 2002 to 150,000 by 2007. The cattle will be largely stall-fed, eating cornstalks, wheat straw, and the harvest from a drought-tolerant leguminous forage crop resembling alfalfa, which is growing on reclaimed land. Local officials estimate that this program will double incomes within the county during this decade.[48]

To relieve pressure on the country's rangelands, Beijing is asking herders to reduce their flocks of sheep and goats by 40 percent. But in communities where wealth is measured in livestock numbers and where most families are living in poverty, such cuts are not easy or likely unless alternative livelihoods are offered along the lines proposed in Helin County. Indeed, unless governments, with support from the international community, can devise comprehensive programs to bring the size of grazing flocks and herds down to the carrying capacity of the land, grasslands will continue to deteriorate.[49]

One of the big challenges is to eliminate overgrazing on the two fifths of the earth's land surface classified as rangelands. The only viable option in many cases is to reduce the size of flocks and herds. But this is not easy in pastoral communities where livestock are the sole means of livelihood. Not only do the growing numbers of cattle, and particularly sheep and goats, remove the vegetation, but their hoofs pulverize the protective crust of soil that is formed by rainfall and that checks wind erosion. Here the solution is to shift to stall feeding of animals, cutting the forage and bringing it to them. Stall-feeding is labor-intensive and thus is a good fit for developing countries with many small holdings, an excess of labor, and a shortage of productive land. As noted, India has been a leader in adopting this practice, particularly within its thriving dairy industry.[50]

Another way to reduce pressure on the land is to shift from the use of fuelwood to renewable energy sources—everything from solar cookers to wind-generated electricity. Protecting the earth's remaining vegetation also warrants a ban on clearcutting forests in favor of selective cutting, simply because with each clearcut, the land typically suffers heavy soil losses until the forest regenerates. Thus with each cutting, productivity declines further.

Restoring the earth's tree and grass cover protects soil, reduces flooding, and sequesters carbon. It is one way we can restore the earth so that it can support not only us, but our children and grandchildren as well.