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World Population Growth, Soil Erosion, and Food Security

Lester R. Brown

As the worldwide effort to expand food production loses momentum, global food insecurity is increasing. The grain surpluses that accumulated in the food-exporting countries during the 1950's and 1960's have disappeared. Even though idled U.S. cropland has recently been returned to production, world food supplies are tightening and the slim excess of growth in food production over population is narrowing (*1*).

Pressures on the world's cropland base are intensifying everywhere. In their efforts to keep up with the doubling of world food demand since mid-century, many of the world's farmers have adopted agricultural production practices that are leading to excessive rates of soil erosion. Even as pressures on cropland from within agriculture intensify, population growth and industrialization are generating pressures to convert cropland to nonfarm uses. The net effect of these trends in a world with little new land to bring under the plow is a loss of momentum in the growth of world food production.

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The Loss of Momentum

The middle of the 20th century was a watershed in the evolution of world agriculture. From the beginning of agriculture until 1950 most increases in food output came from an expansion of the area under cultivation. Since then, most have come from raising yields on existing cropland through the use of energy-intensive inputs—principally chemical fertilizers and irrigation.

Mid-century also marked the beginning of an unprecedented growth in food production. Between 1950 and 1971, the world's farmers increased grain production from 631 million metric tons to 1237 million tons (see Table 1). In just 21 years, output nearly doubled. In per capita terms, this period was also one of impressive progress. World cereal production per person climbed from 251 kilograms in 1950 to 330 kilograms in 1971, a gain of 31 percent. Diets improved measurably in many Third World countries, and the consumption of livestock products climbed steadily throughout the industrial world.

The years between mid-century and 1972 represented a unique period in the world's food economy. The excess production capacity that translated into surplus stocks and cropland idled under U.S. farm programs assured remarkably stable food prices. This period came to an abrupt end with the massive Soviet wheat purchase in 1972, when the decision was made to import grain rather than ask consumers to tighten their belts. Within months the world price of wheat had doubled and famine had returned to the Indian subcontinent, Africa, and elsewhere after an absence of a quarter-century.

Since 1971, gains in output have barely kept pace with population growth; production per person has fluctuated widely but shown little real increase. A review of the rate of growth in grain production by decade shows a clear loss of momentum. Per capita grain production worldwide climbed 14 percent during the 1950's, 8 percent during the 1960's, but only 5 percent during the 1970's. In Africa, where population growth during the 1970's was the fastest ever recorded for any continent, the food safety margin disappeared entirely as growth in food production fell below that of population. The 14 percent decline in per capita grain production in Africa during that decade was the first sustained continent-wide decline since World War II.

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Declining Food Security

From the late 1940's through the early 1970's, the world enjoyed an unprecedented period of food security. Grain carry-over stocks—the grain in bins when the new harvest begins—were available for use when needed. Idled U.S. cropland could be brought back into production within a year. Together, these two reserves provided security for all humanity, a cushion against any imaginable disaster.

As recently as 1969, the amount of grain that was either held in storage or that could be produced within a season on idled U.S. cropland amounted to 91 days of world consumption. Following poor harvests in key producing countries in 1972 and 1974, world reserves fell to only 40 days (see Table 2). At this level, grain stocks constituted little more than pipeline supplies, barely enough, that is, to fill the supply line between the farmer and the ultimate consumer. Shortfalls in harvests during the mid-1970's meant that the rebuilding of the world food reserves depleted in 1972 was put off until 1976. With some uncommonly good harvests in the late 1970's, the food situation stabilized temporarily. But in 1980, a poor harvest in the Soviet Union and a mediocre one in the United States drew world food reserves down to a near-record low.

The world enters the 1980's with only one of its two traditional reserves—carry-over stocks of grain. For the first time in close to a generation, there is no cropland idled under U.S. farm programs. The loss of this reserve, which provided security for the entire world, may be permanent. Carry-over stocks of grain in 1980 amounted to 40 days' worth of consumption. In 1981, they are expected to fall somewhat further. Except for 1974 and 1975, when reserves dropped to 40 days of consumption after bad weather reduced the harvest, food supplies have not been this low since World War II.

Given the intertwined global food economy, food insecurity increases everywhere as agriculture is extended into marginal areas. Although the Soviet "virgin lands" are a major source of bread for Soviet tables, they are in an area of light and highly variable rainfall, subject to crop failure one year in every three or four. When the Kremlin decided to offset these periodic shortfalls by increasing imports, the instability that had been confined to the Soviet food economy spread to the entire world.

Soil erosion, now accelerating on every continent, also contributes to food supply instability. When the organic matter in soil is reduced as a result of erosion, the soil's water-retention capacity declines so that the land becomes more vulnerable to short-term dry spells. A study by the U.S. Center for Environmental Assessment Services showed that eroded soils that had a yield 30 percent less than a non-eroded control plot also had a yield that was four times more variable (*2*). Too often, efforts to expand output by extending cultivation onto marginal land increase harvest variability and global food insecurity.

Summary. Since 1950, world food output has more than doubled, but in many cases this impressive gain has been achieved by the adoption of agricultural practices that lead to an excessive rate of soil erosion. At least one-fifth, and perhaps as much as one-third, of the global cropland base is losing soil at a rate that is undermining its long-term productivity. World food production per person will eventually begin to decrease if the loss of topsoil continues at current rates. In view of this, there is an urgent need to realign national priorities everywhere in order to get the brakes on world population growth and to finance the adoption of agricultural practices that will preserve the cropland base.

The Return of Famine

From World War II through 1971 the United States intervened unilaterally with food-aid shipments wherever famine threatened. For example, after consecutive monsoon failures in India in 1965 and 1966, the United States shipped a fifth of its wheat crop to that country in two consecutive years to avert famine. In recent years the United States has attempted to shift the responsibility for responding to famine to the international community, but in times of worldwide shortage, this community can no longer be relied on to respond effectively to crop shortages in poor countries.

The food scarcities and oscillating grain prices of the early 1970's brought the return of famine. The poorest countries were among the hardest hit. With two poor harvests during the early 1970's, Bangladesh saw death rates climb sharply twice. An estimated 427,000 lives were lost in 1971–1972 and another 330,000 in 1974–1975 (*3*). After a weak monsoon and a poor harvest in 1972, the Indian government discovered that the Soviet Union had tied up most of the world's exportable wheat supplies, leaving little for India to use to offset its poor harvest. Thus, the Indian government sat by helplessly while food consumption fell and death rates climbed. In the three poorest states of Uttar Pradesh, Bihar, and Orissa alone there were an additional 829,000 deaths compared to previous years (*3*). This loss of life in India far exceeded the total combat fatalities suffered in any war since World War II.

During the 1970's, hunger also took a heavy toll in Africa, where a prolonged drought in the Sahel brought the deteriorating food situation into sharp focus. Senegal, Mauritania, Niger, Upper Volta, Chad, and Mali all lost lives. Further east in Africa, the ecological deterioration of Ethiopia's food system was also made all too apparent by a drought that claimed an estimated 200,000 lives and brought Haile Selassie's 47-year reign to an end (*4*).

Although grain stocks were partially rebuilt in the late 1970's, the global balance between demand and supply has again become delicate, as the sensitivity of commodity prices to weather reports attests. Now, a poor harvest in a major producing country can set off a wave of global inflation. In poor countries, where rising food prices can push death rates upward, reduced harvests can have a demographic, as well as an economic, impact.

The North American Breadbasket

Another source of world food insecurity is the dependence of the entire world on North America for food supplies (see Table 3). This unhealthy dependence has both meteorological and political dimensions, since the United States and Canada are affected by the same climatic cycles and since heavy dependence on any two countries for grain gives these governments extraordinary political power.

Prior to World War II, Western Europe was the only grain-importing region. North America was not the only exporter nor even the leading one. During the late 1930's, Latin American grain exports were nearly double those of North America, and Eastern Europe (including the Soviet Union) was exporting 5 million tons annually, the same amount as North America. All this has now changed beyond recognition. Asia has developed a massive deficit. Africa, Latin America, and Eastern Europe all import food. Western Europe, consistently importing 15 to 30 million tons, has been the most stable element throughout the period. North America's emergence as the world's breadbasket began in the 1940's. The scale of exports expanded gradually during the 1950's and 1960's, but then more than doubled during the 1970's as scores of countries began to lose the capacity to feed themselves.

This dramatic transformation of intercontinental food flows reflects wide differences in population growth, widely varying levels of agricultural management, and, in many countries, a rate of soil erosion that is draining cropland of its fertility. As recently as 1950, for example, North America and Latin America had roughly equal populations—163 million and 168 million, respectively. But while North America's population growth has tapered off substantially since then, Latin America's has escalated. Mexico, Venezuela, Peru, and Brazil all have population growth rates of close to 3 percent per year. Had North America's 1950 population expanded at 3 percent per year, it would have reached 395 million in 1980 (rather than the actual 248 million), absorbing virtually all the region's exportable surplus and leaving the continent struggling to maintain self-sufficiency.

Today, over a hundred countries rely on North American grain. The worldwide movement of countries from export to import status is a much traveled one-way street. The reasons vary, but the tide is strong: no country has gone against it since World War II. Literally scores of countries have become food importers, but not one major new exporter has emerged.

For most countries, the need for imported food is more likely to increase than decrease. Agricultural mismanagement and inefficiency have taken their toll on food production, particularly in the Third World and the centrally planned economies of Eastern Europe. It is difficult, for example, to see how the Soviet Union can avoid importing even more grain in the near future. Indeed, 1982 Soviet grain imports will almost certainly exceed 40 million metric tons, more than any country has ever imported (*5*).

Other countries also face rapidly growing deficits. Egypt has little opportunity for expanding its agricultural base and yet its population is growing rapidly. According to International Food Policy Research Institute projections, Nigeria will have a food deficit of at least 17 million tons of grain annually by 1990 if recent trends continue (*6*). Mexican grain imports are growing by leaps and bounds, and unless the country loses an even larger fraction of its population through illegal migration to the United States, this trend is likely to continue. The story is fundamentally the same in scores of countries.

Table 1. World grain production, total and per capita, 1950 to 1980. For sources of data, see (*42*).

Year	Population (billions)	Grain production: Total (million metric tons)	Grain production: Per person (kilograms)
1950	2.51	631	251
1960	3.03	863	285
1970	3.68	1137	309
1971	3.75	1237	330
1972	3.82	1197	314
1973	3.88	1290	332
1974	3.96	1256	317
1975	4.03	1275	316
1976	4.11	1384	337
1977	4.18	1378	330
1978	4.26	1494	351
1979	4.34	1437	331
1980*	4.42	1432	324

*Preliminary estimate.

Although the need for imported grain is projected to continue growing, the capacity of North America to respond to these demands may ultimately be overwhelmed. The disappearance of idled cropland, the growing use of U.S. grain in alcohol-fuel distilleries, and the projected decline in irrigated acreage in key farm states all make it more difficult to sustain the rapid growth in North American food exports on which the world has none too wisely come to rely.

Behind this trade issue, a philosophical debate is beginning to emerge on the wisdom of adopting agricultural practices that lead to excessive soil erosion in order to meet the ever-growing world demand for grain. Many agricultural analysts and environmentalists now argue that it makes little sense to sacrifice a resource that has been a source of economic strength since colonial days merely to buy a few billion barrels of oil. The current trend is fraught with risks both for those whose livelihoods depend on land being productive and for those in countries dependent on food imports that will dry up if this mining of soils continues. Even for the importing countries, lower imports and a reduction in pressure on North American soil resources in the short term would be better than losing the region's export capacity over the long run.

Conversion of Cropland to Nonfarm Use

Agriculture's principal competition for land comes from urban expansion, village expansion, energy production, and highway construction. In the United States, nearly a million acres of prime cropland were converted to nonfarm uses each year between 1967 and 1977 (*7, 8*). In the extreme case of Florida—source of half the grapefruits in the world and a quarter of the oranges—all the prime farmland will be put to other uses by the end of the century if current trends continue. In Virginia, 24 percent of the prime cropland could be lost; in California, 16 percent (*9*).

Rural states are also feeling the squeeze. According to Allen Hidlebaugh

Table 2. Index of world food security, 1960 to 1980. For sources of data, see (*43*).

Year	Reserve stocks of grain (million metric tons)	Grain equivalent of idled U.S. cropland (million metric tons)	Total reserves (million metric tons)	Reserves as days of world consumption (days)
1960	198	36	234	102
1965	143	70	213	80
1970	165	71	236	77
1971	183	46	229	73
1972	142	78	220	66
1973	147	25	172	51
1974	132	4	136	40
1975	138	3	141	40
1976	192	3	195	55
1977	191	1	192	51
1978	218	21	239	62
1979	191	15	206	51
1980	151	0	151	40

Table 3. The changing pattern of world grain trade. The results are expressed as million metric tons of grain; plus signs indicate net exports; minus signs, net imports. For sources of data, see (*44*).

Region	1934 to 1938	1948 to 1952	1960	1970	1980
North America	+5	+23	+39	+56	+131
Latin America	+9	+1	0	+4	−10
Western Europe	−24	−22	−25	−30	−16
Eastern Europe and Soviet Union	+5	0	0	0	−46
Africa	+1	0	−2	−5	−15
Asia	+2	−6	−17	−37	−63
Australia and New Zealand	+3	+3	+6	+12	+19

of the National Agricultural Lands Study staff, "even in America's agricultural heartland—the corn belt states—there is cause for concern. We anticipate a total 3.2 million acre prime farmland loss in Iowa, Illinois, Indiana, Ohio, and Missouri combined. If present trends continue to the year 2000, the annual loss will equal 480 million bushels of corn—at \$2.50 a bushel, a permanent loss of \$1 billion a year, every year, by the century's end" (*10*).

Data on changing land use elsewhere confirm that the growth of cities is a leading source of cropland loss. A study of urban encroachment on Europe's grazing lands and croplands from 1960 to 1970 found that West Germany lost 1 percent of its agricultural land every 4 years. For France and the United Kingdom, the loss was nearly 2 percent over the decade (*11*). For the Third World, information on land lost to rapid urbanization is less reliable but United Nations demographers expect the world's urban population to expand from 1.81 billion in 1980 to 3.16 billion in 20 years (*12*). If this projected increase created a need for only 0.04 hectares per person, then the world's cities would occupy an additional 54 million hectares of land by the year 2000. If 40 percent of this total is converted cropland, cities will be built on an area as large as the cultivated area of France (*13*).

Although this projected loss would amount to less than 2 percent of the world's cropland, the impact on global food output is likely to be greater, since cities are usually situated on the most fertile soils. A study of changing land-use patterns in Canada reports that "half of the farmland lost to urban expansion is coming from the best one-twentieth of our farmland" (*14*). But even if the best does not go first, the worldwide loss of 25 million hectares would mean the loss of enough food to feed some 84 million people.

Even outside cities, habitats claim farmland. In the Third World, village growth extends into agricultural fields. Living space requirements of the 14 million people added to India's population each year are at least partly met by homes built on cropland surrounding the nation's cities and 600,000 villages (*15*). Further east, China is also losing cropland to cities and industry. Alva Erisman, a China specialist with the U.S. Department of Agriculture, reports that "water control projects, urban growth, and the appropriation of agricultural land for roads, railroads, airfields, industrial plants, and military uses has removed good farmland from cultivation" (*16*). Dwight Perkins, Chinese scholar at Harvard, makes the same point, noting that the 10 percent annual growth in modern industry has occurred partly at the expense of agricultural lands next to the city limits, where most factories spring up (*17*).

Rivaling urbanization as a claimant on cropland is energy production. Hydroelectric dams sometimes inundate vast stretches of rich bottomland, even as they add to the irrigated area. In the United States, where coal production is projected to climb steadily, some of the most accessible reserves of coal are by an accident of geography directly beneath some of the nation's finest farmland. In congressional testimony, the zoning administrator of coal-rich Knox County, Illinois, indicated that strip mining threatened 284,000 acres of farmland in his county alone (*18*).

How much cropland will be paved over, built on, strip mined, or flooded over the remainder of this century is unknown, but if the projected growth in population and income should materialize, then urbanization, energy production, and transportation are certain to continue encroaching upon cropland.

Although the hunger for land has never been greater, the amount of cropland abandoned each year as economic pressures interact with ecological forces may also be at a record high. On balance, it is difficult to envisage an increase in the cropland base of much more than 10 percent by century's end. With projected population growth, this modest increase would leave us in the year 2000 with only 0.13 hectare of cereal land per person, nearly a quarter less than the 0.17 hectare we each now have (see Table 4).

Thinning Topsoil

Just as important to food production as the amount of land available to produce crops is the condition of the soil. Only inches deep (usually less than a foot) over much of the earth's surface, topsoil forms a fertile carpet over less productive subsoils. As the topsoil layer is lost, subsoil becomes part of the tillage layer, reducing the soil's organic matter, nutrient content, water-retention capacity, aeration, and other structural characteristics that make it ideal for plant growth.

Soil erosion is a natural process, one that occurs even on land in grass or in forests. But on land that is cleared and cropped, erosion often accelerates. Whenever the pace of erosion exceeds the natural rate of soil formation—what soil scientists call the tolerance or "T factor"—the topsoil thins and eventually disappears, leaving only subsoil or even bare rock. New soil formed by natural processes commonly ranges from 2 to 5 tons per acre per year. Only when the soil erosion exceeds this does the land begin to lose its long-term productivity.

As the worldwide demand for food mounts, cultivation is being so intensified on some soils that excessive erosion and a gradual decline in inherent soil fertility are resulting. Elsewhere, cultivation is being extended onto less productive, erosion-prone soils. For most countries, the increasing demand for food is internally generated, but for the United States the stresses on soils come from growing food deficits worldwide.

Within the United States, this mounting demand for food since mid-century, combined with the availability of cheap nitrogen fertilizer, has led farmers to abandon traditional rotations that included soil-retaining pastures and hay in favor of continuous cropping of corn and other row crops. As a result, the overall gains in grain production since mid-century have been impressive, but the price paid in lost topsoil has been high. Fourteen years of data gathered at the Missouri Agricultural Experiment Station show land planted to a corn-wheat-clover rotation losing an average of 2.7 tons of topsoil per acre annually through erosion, whereas comparable land planted continuously to corn lost 19.7 tons per acre annually (*19*). Although the former amount is well within the tolerance range established by soil scientists, the latter leads to a progressive thinning of the topsoil layer. In Iowa alone, 260 million tons of soil are lost from cropland each year. According to the Iowa State University Experiment Station, that soil "simply cannot be replaced within our lifetime or those of our children. The eroded soil is gone, depleting the fertility of the land" (*20*).

Concern with these trends in the United States led in 1977 to the passage of the Soil and Water Resources Conservation Act, which called for a detailed survey of the state of U.S. soils. Soil scientists discovered "alarmingly high" rates of erosion by water in several states (*7*). Tennessee, for example, was losing an average of 14.1 tons of topsoil per acre of cropland; Missouri, 11.4 tons; Mississippi, 10.9 tons; and Iowa, 9.9 tons. In the Great Plains, wind erosion was particularly severe, claiming an average of 14.9 tons per acre in Texas and 8.9 tons in Colorado.

Nationally, water erosion alone removes annually some 2 billion tons of U.S. topsoil—just over a billion tons more than is formed each year (*7*). If one assumes 160 tons per acre-inch of soil and a typical topsoil depth of 8 inches, this billion tons represents the loss of 781,000 acres of cropland equivalent per year. One obvious way of curbing this excessive loss would be to return to rotation cropping, but unfortunately this less intensive form of cultivation would not yield enough to satisfy grain needs abroad.

Elsewhere in the world, the doubling of demand for food over the past generation has forced farmers onto dry and steep lands, which are inherently susceptible to erosion. In the Third World, record rates of population growth have forced farmers onto mountain soils, leaving them no time to construct terraces. Once the natural cover is removed, the topsoil quickly washes into adjacent valleys, where it silts streams, reservoirs, and canals.

In Andean Latin America, skewed land ownership patterns can aggravate this problem. Wealthy ranchers use the relatively level valley floors for cattle grazing, forcing small landholders onto steep slopes to produce subsistence crops. This pattern leads to severe soil erosion on the slopes, which impairs the productivity of both the mountainsides and the valleys.

Table 4. World population and area in cereals, 1950 and 1980, with projections to 2000. For sources of data, see (*45*).

Year	Population (billions)	Area in cereals (million hectares)	Area per person (hectares)
1950	2.51	601	0.24
1980	4.42	758	0.17
2000	6.20	828	0.13

Where farmers have discontinued fallowing and other restitutional agricultural practices, compensatory measures may only be of limited value. In the Soviet Union, attempts to regain food self-sufficiency by investing heavily in agriculture are stymied because soils have lost some of their inherent productivity. Measuring extreme degradation of croplands in terms of gully formation, soil scientists at the Soil Erosion Laboratory at Moscow University have found that while only 2 percent of the south central Soviet Union shows severe gullying, as much as 50 percent of the land could follow suit as efforts to intensify agriculture proceed (*21*). A parallel Soviet study of the present gully network in the Steppe and Forest Steppe regions in the European U.S.S.R. found that gully formation accelerated as "good land reserves became exhausted and sloping land began to be plowed (*22*). In an analysis of Moscow's agricultural plans, Gustafson observes that the Soviet government must now reckon with "50 years of neglect [that] have left a legacy of badly damaged soils" (*23*).

Even while soil erosion raises the demand in the Soviet Union for food imports, it reduces export capacity elsewhere. For example, Australia is experiencing serious soil erosion as it responds to the growing world demand for grain exports. Canberra-based soil scientist C. L. Watson (*24*) reports that "some 50 percent of our existing agricultural and arid lands need ameliorative measures to just maintain present productivity."

Neighboring Indonesia is experiencing the same neglect. A report from the U.S. embassy in Jakarta indicates that soil erosion is bringing on an " 'ecological emergency' in Java, laying waste to land at an alarming rate, much faster than present reclamation programs can restore it" (*25*). Similar pressures are building in Pakistan's rain-fed agricultural regions. An officer of the Agency for International Development (AID) in the Punjab area reports the annual abandonment of several thousand hectares of cropland because of severe degradation caused by erosion (*26*). In Nepal, the country's rivers now annually carry 240 million cubic meters of soil to India, making that country the recipient of what has been described as Nepal's "most precious export" (*27*).

In Ethiopia, according to an AID report, "there is an environmental nightmare unfolding before our eyes. . . . It is the result of the acts of millions of Ethiopians struggling for survival: scratching the surface of eroded land and eroding it further; cutting down the trees for warmth and fuel and leaving the country denuded. . . . Over one billion—one billion—tons of topsoil flow from Ethiopia's highlands each year" (*28*). In South Africa, biologist John Hanks estimates that the province of Natal, incorporating Kwazulu, is losing 200 million tons of topsoil annually (*29*).

Far from complete, this litany of disasters merely suggests the scope and impact of soil erosion. A 1977 United Nations survey reported that almost one-fifth of the world's cropland is now being steadily degraded, but more recent data indicate that it could be closer to one-third (*30*). In the United States, 34 percent of all cropland is losing topsoil at a rate that is undermining long-term productivity (*31*).

Underscoring the gravity of the erosion threat is convincing evidence that the adoption of erosion-control practices is often not cost-effective for the farmer. An interdisciplinary team of agricultural scientists studied land in southern Iowa where erosion was excessive and calculated the projected near-term costs of erosion in terms of additional energy use, additional fertilizer use, and reduction in yields. They found that the costs of reducing soil erosion to a tolerable level came to three times the immediate economic benefits of doing so (*32*). Unless governments share the cost of erosion control practices, a typical farmer with a narrow profit margin and with land suffering from excessive erosion appears to have two choices: adopt the costly erosion control measures needed and face bankruptcy in the near term, or continue with business as usual until eventually the inherent productivity of the land falls to the point where it must be abandoned.

The tough choice confronting farmers in the U.S. Midwest must be made the world over. Differences in economic systems notwithstanding, the same basic pressures on the land are at work everywhere. In the interaction between the demands of the economic system and the tolerance of ecological systems, ideological boundaries count for little.

Land Productivity Trends

In a world where 70 million new residents are added each year and where little fertile new land awaits the plow, land productivity is the key to the food prospect. Following World War II, crop yields began to rise in a sustained, systematic fashion in virtually every industrial country. During the 1960's, the introduction of the fertilizer-responsive varieties of wheat and rice enabled many Third World countries to raise food output per hectare too. Between mid-century and the early 1970's the steady rise in cereal yield per hectare was one of the most predictable trends in the world economy, increasing at an average of 2.2 percent annually. Since 1970, however, the rate has fallen to 1.6 percent per year as idled (and usually marginal) U.S. cropland was returned to production and as the price of energy-intensive inputs rose (see Table 5).

Numerous factors appear responsible for the drop in the rate at which yields have been increasing. In most instances the new cropland being brought under the plow is of lower quality than the land already in use. Often the marginal land added replaces prime land that has been withdrawn for nonfarm uses, leading to a reduction in land quality that is not evident from data on overall cropland area.

Also sapping farmland productivity is the reduction of fallow area in dryland farming regions. As world wheat prices rose between 1969 and 1974, summer fallow land in the United States dropped from 17 million to 13 million hectares (*33*). The stresses are evident in other dryland farming regions as well. The U.S. agricultural attaché in Moscow reported a strikingly similar reduction in fallow land in the Soviet Union from 17 million to 12 million hectares after the massive crop shortfall and heavy imports of 1972 (*34*).

In tropical and subtropical regions, where fallowing evolved as a method of restoring fertility, mounting population pressures are forcing cultivators to shorten rotation cycles and thus to undermine the land's productivity. In Nigeria, for example, where farming has been expanded onto marginal land and fallow cycles shortened, cereal yields have been falling since the early 1960's. A World Bank study of Nigeria reports

Table 5. World production, harvested area, and yield of cereals, 1950 to 1980. For sources of data, see (*46*).

Year	Production (million metric tons)	Area (million hectares)	Yield (metric tons per hectare)
1950	631	601	1.05
1960	863	682	1.26
1970	1137	704	1.62
1980	1432	758	1.89

"fallow periods under shifting cultivation have become too short to restore fertility in some areas" (*35*). In some locales, the original cropping cycle of 10 to 15 years has already been reduced to 5 years.

While the shortening of fallow cycles is reducing land productivity in some countries, soil erosion is reducing it in others. One of the big unknowns facing agricultural analysts is how rapidly excessive soil erosion will reduce land productivity. The U.S. Department of Agriculture estimates that if this erosion continues in the U.S. corn belt, "potential corn and soybean fields would probably be reduced by 15 to 30 percent on some soils by the year 2030." A study of the erosion of Piedmont soils in Georgia showed a 6-inch loss of topsoil reducing average yields 41 percent. A similar degree of erosion in West Tennessee led to a 42 percent drop in corn yields (*36*).

The Loss of Irrigated Land

Irrigated lands, which provide a disproportionately large share of the world's food, are also being threatened, both by ecological forces—waterlogging and salinity—and by economic forces that divert water to competing uses. In addition, some land is being irrigated by so-called "fossil water," that is, water from aquifers that cannot be recharged. For the world as a whole, irrigated acreage is still expanding since the area in new projects exceeds losses. But in some locales, irrigated acreage is shrinking.

Waterlogging and salinity helped undermine some of the earlier Middle Eastern civilizations. Although the designers of the earliest irrigation systems in the Tigris-Euphrates Valley did not understand subterranean hydrology well enough to prescribe corrective action, modern irrigation engineers do. Now the problem is the cost: according to a recent United Nations estimate, average salvage costs are $650 per hectare (*30*).

Worldwide data compiled by the United Nations indicate that one-tenth of the world's total irrigated area is waterlogged—some 21 million hectares (*30*). The productivity on this land has fallen by 20 percent, and almost as much land has been rendered less productive by salinization. Although fully half the world's irrigation capacity has been developed since 1950, those gains are already being undermined by waterlogging and salinity. These modern experiences with irrigation mirror the experience of the early Mesopotamian civilization, though on a far larger scale. In the current agronomic literature of China, references to the problem abound. And along the Nile River, the more-intensive irrigation made possible by the Aswan high dam has upset the long-standing water balance, leading to the waterlogging and salting of some Egyptian soils historically free of this problem. Many farms in the American Southwest have drainage systems that remove the salt from irrigated fields, but some of that unwanted salt ends up in river waters that eventually irrigate Mexican crops.

Rehabilitating waterlogged soils takes time and prodigious amounts of capital—witness the heavy Soviet investments in agricultural land reclamation and irrigation. In Pakistan, a country almost entirely dependent on irrigation for food production, waterlogging and salinity affect the productivity of much of the land (*37*). Thanks only to heavy investments in reclamation, much of it from foreign aid, the process has been reversed.

Besides the endemic problems irrigation is subject to, increasing urban and industrial demands for water in arid areas threaten the future of irrigated agriculture. Two cases in point are those of the Soviet Union's south central region and the U.S. Great Plains and Southwest. Soviet efforts to regain food self-sufficiency rest heavily on attempts to expand irrigation, but ambitious plans and heavy capital commitments may fly in the face of reality if the water shortages predicted for the southern half of the country materialize. In Arizona, the irrigated area in agriculturally important Maricopa County is shrinking steadily as water is diverted to the rapidly expanding Phoenix metropolitan area. Between the late 1950's and the early 1970's, the irrigated area fell from 224,000 to 177,900 hectares (*38*). Yet even with reduced agricultural demands, ground-water levels have been dropping by some 10 to 20 feet per year.

California has similar problems, though on a larger scale. As a result of Los Angeles' thirst, irrigated valleys that were once lush green have now turned to dusty brown. However wasteful and illogical, urban claims nearly always take precedence over farm demands for water, because of economics, politics, or both.

In the southern Great Plains of the United States, irrigated agriculture is threatened by the depletion of the vast Ogallala aquifer, the water-bearing stratum that underlies the western plains from Nebraska south to Texas. The land atop this aquifer accounts for much of the growth in U.S. irrigated acreage since 1945. Many of the country's largest beef feedlots developed here because of a unique combination—a dry climate and plentiful supplies of grain sorghum, corn, and alfalfa grown on irrigated land. But the Ogallala aquifer is essentially nonrechargeable, so the extensive irrigation in parts of Nebraska, Kansas, Colorado, Oklahoma, Texas, and New Mexico can only be short-lived. A study of 32 counties in the Texas panhandle, where the aquifer is uncommonly shallow, estimated that by 1995 fuel increases and water-table depletion will eliminate irrigation entirely there, forcing a return to dryland farming (*39*).

In the western United States, efforts to develop the extensive coal and oil-shale resources will divert still more water from agriculture. One study concludes that "water demands for energy development compound urban pressures upon irrigated agriculture. Every recipe for energy development has 'add water' in its instructions" (*40*). This analysis indicates that "a coal gasification plant in New Mexico or Arizona, processing 24 million tons of coal per year to meet the energy needs of a million people, would use about 300,000 acre feet of water per year. A 10,000-megawatt coal-fired thermal electric power plant in the Four Corners region requires about 230,000 acre feet of water per year" (*40*).

While waterlogging and salinity have long been undermining irrigated land, the wholesale diversion of water from agriculture to cities and industries is more recent. It promises to become an even more contentious issue in the future. Even now, each new diversion of water from agriculture to other uses adds to the upward pressure on food prices.

Conclusions and Recommendations

As the 1980's begin, the growth in world food production is losing momentum and its excess over population growth is narrowing. If soils continue to deteriorate in Africa, the decade-long decline in food output per person there could become chronic. If soil erosion and the other forces that have slowed food production in the world as a whole continue to intensify, and if the projected increases in population materialize, then growth in food production could fall below that of population for the world as a whole during the present decade.

Responding effectively to the cropland threats associated with mounting food demands poses a dilemma for farmers and governmental planners alike. Although economic forces and political instincts encourage a short-term focus, pressures to wring too much out of the land in the short run can destroy it over the long run. The key to an effective worldwide response is a wider public understanding of the long-term effect of cropland conversion and topsoil loss on food prices. Countries have pulled back from disaster's edge before. In the United States an earlier generation overcame the Dust Bowl threat, and China's longest march may have been that on the road to agricultural recovery since 1949.

In the United States the Soil Conservation Service has outlined a national plan that would bring the annual loss of topsoil down to a tolerable level. In addition to maintaining the conservation systems already in place, some 158 million acres of the 413-million-acre cropland base need additional attention. Of this total, 17 million acres of cropland are eroding so rapidly that the Soil Conservation Service recommends that it be shifted from continuous row cropping and converted to woodland, grassland, or long-term rotation. The remaining 141 million acres of cropland that are currently losing more than 5 tons of soil per year require the adoption of some form of conservation tillage such as terracing, contour farming, strip cropping, or minimum tillage (*7*).

Indian officials are wrestling with the same issues that trouble U.S. officials and soil scientists. Although it has three times as many people as the United States, India has a cropland base that is almost exactly the same size, roughly 350 million acres, but political support for soil conservation is minuscule. Despite the highly visible deforestation of the Himalayas, the denudation of watersheds, and the increasing frequency of crop-destroying floods, the problem is not being addressed. According to B. B. Vohra, a senior Ministry of Irrigation official, "Even at the national level, there is as yet not even a broad perspective plan for the care of the land, no exact information regarding the extent and the location of lands which require protective and ameliorative treatment, and no agency specifically charged with the responsibility for the assessment and management of our irreplaceable land and soil resources" (*41*).

In the Soviet Union, the loss of topsoil appears to be even greater than it is in the United States. Indeed, mounting Soviet dependence on imported food is due less to a lack of land than to low productivity. Few Soviet consumers are even aware of the threat, and governmental support for remedial action is even weaker in the Soviet Union than in India.

In many Third World countries an adequate effort to arrest the excessive loss of topsoil will require program expenditures that may well exceed the current entire budget of their respective ministries of agriculture. In some countries the funds required could rival military expenditures. What governments everywhere must consider is the realigning of priorities that will permit soils to be stabilized. To meet future food demands we must preserve the agricultural land that is the foundation of civilization, redoubling efforts to protect cropland both from soil erosion and from conversion to nonfarm uses.

Essential though efforts to protect the cropland base are, they are not in themselves adequate. If humanity cannot get the brakes on population growth, reducing future growth below even the lowest level now projected by the United Nations demographers, then an eventual decline in world per capita grain production may be inevitable. Without a major advance in family planning efforts, the downturns in recent years of the per capita fish catch and per capita beef production may soon be overshadowed by the decline of per capita production of food.

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