*Lester R. Brown*

# THE FOOD PROSPECT

The world food economy has undergone a basic transformation during the seventies.* Not only did the world have surplus stocks and excess production capacity at the beginning of the decade, but it also appeared that both would be around for a long time to come. Suddenly in 1972 and 1973, they disappeared and the whole world was trying to make it from one harvest to the next. During the mid-seventies global food insecurity was greater than at any time since the war-torn years immediately following World War II.

The delicate balance between the global supply and demand for food is illustrated in the extreme sensitivity of commodity prices to weather reports. A weather report from western Kansas indicating that precipitation is expected over the week-end can send wheat futures prices down the daily limit on the Chicago Board of Trade. A report from the Soviet Union indicating that the winter kill in the winter wheat crop will be greater than expected, can send wheat prices up the limit. When supply and demand are so precariously balanced, a major crop shortfall in an important producing country can measurably affect global inflation rates. In poor countries, it can also have a demographic impact as rising food prices push death rates upward.

* This article is drawn from a forthcoming book, *The Twenty-Ninth Day*.

NEW SOURCES OF FOOD INSECURITY

Throughout most of the period since World II, the world had two major food reserves; stocks of grain held by the principal grain-exporting countries and cropland idled under farm programs in the United States. Some 50 million acres out of a total U.S. cropland base of 350 million acres was held out of production to support prices. Together grain stockpiles and the U.S. cropland reserve provided security for all mankind, a cushion against any imaginable food disasters.

As recently as early 1972, it seemed likely that surplus stocks and cropland idled under farm programs would remain part of the landscape for the foreseeable future. But, then, the rapidly growing global demand for food began to outstrip the productive capacity of the world's farmers and fishermen. The world fish catch ceased expanding. By 1974 all of the idled U.S. cropland had been released for use, but food reserves were still not rebuilt.

In 1961, the combination of reserve stocks of grain in exporting countries and idled cropland in the United States amounted to the equivalent of 105 days of world grain consumption. Then reserves began to drop rather abruptly—to 55 days in 1973 and still further to 31 days in 1976. All of the idled cropland was released for production by 1974, entirely eliminating this reserve. A record grain harvest in 1976 in three of the world's four leading food producing countries—the United States, the Soviet Union and India—has led to a modest rebuilding of stocks, though not nearly enough to cushion adequately even one poor world harvest. Since both the United States and Canada are affected by the same climatic cycle, a poor crop in one is often associated with a poor crop in the other.

The decision in 1972 by Soviet political leaders to offset crop shortfalls with imports has further added to the instability. Aside from the additional pressures on exportable grain supplies, the vast year-to-year fluctuations in the Soviet grain harvest are greater than the annual gains in the world grain crop. Wide swings in the size of the Soviet harvest that were once absorbed within the country must now be absorbed

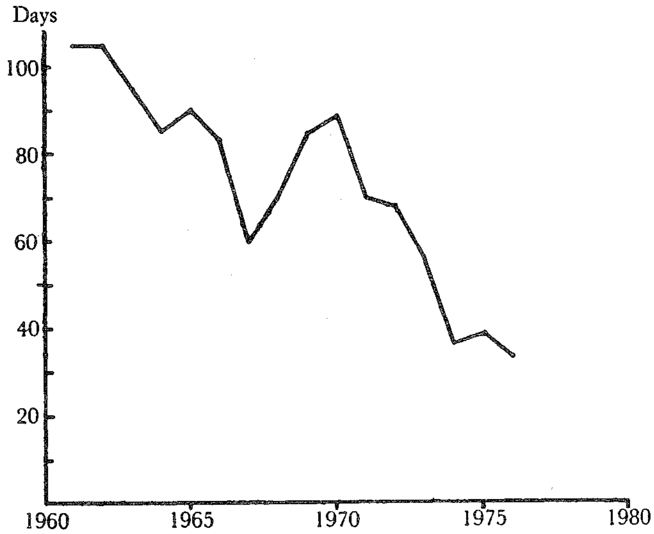


Fig. 1: World Grain Reserves as Days of World Consumption, 1960-76.

elsewhere. The Soviet decision to import may not be an irreversible one, but neither will it be easily turned around. It has facilitated the expansion of Soviet livestock herds and poultry flocks, which has in turn raised the expectations and appetites of Soviet consumers.

The high costs of food price instability take many forms—economic, political, and social. Consumers, particularly the poor, obviously suffer. Most families cannot easily adjust to wide fluctuations in food prices. Nor can producers easily decide how much to plant and how much to invest in inputs when prices are in constant flux. When grain prices soar, dairymen and cattlemen everywhere get trapped in a near impossible bind; if they keep the price of milk or beef at levels that the consumer can afford, they themselves cannot afford the grain they need for cattle feed.

Violent fluctuations in food prices also make economic



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planning difficult for governments. Unstable food markets wreak havoc with foreign exchange budgets, particularly those of countries heavily dependent on food imports. They also undermine efforts to combat inflation. Indeed, soaring food prices have contributed importantly to the global double-digit inflation of the mid-seventies.

## DEMAND SIDE OF THE EQUATION

Food insecurity derives not from production failures but rather from unprecedented growth in food demands. Farmers and fishermen are trying harder and investing more to expand production than ever before. The record growth in demand for food, some 30 million tons of grain per year in good weather or bad, is fueled both by the relentless growth of population and by growing affluence.

Since consumption per person increased little if at all during most of human history, population growth long generated nearly all growth in food demand. Only since World War II has rising affluence become an important factor at the global level. In West Germany, where population growth has ceased, and in Japan, where population growth is negligible compared with income growth, increases in food consumption derive almost entirely from rising affluence. More generally, rising affluence accounts for 8 of the 30 million tons of grain needed to satisfy the yearly growth in demand.

At the opposite end of the spectrum, are the poorer countries such as India in which per capita incomes are rising little if at all and in which population accounts for virtually all the growth in food consumption. In Brazil, both the rapid population growth and the rapid economic growth of the past decade have combined to create one of the most rapid overall increases in demand ever experienced by any country. This helps explain why Brazil has emerged as one of the largest cereal importers in the Western Hemisphere.

The impact of population growth on food needs is rather straightforward. Each year the world's farmers and fishermen, already straining to feed some 4 billion people, must attempt to feed 65 million more people. Each day 178,000 new faces appear at the breakfast table. India alone must somehow sustain an annual increase equivalent to Australia's population.

The relationship between changes in per capita income and changes in food consumption levels is perhaps easiest to understand when expressed in terms of grain. Grain dominates diets, whether it is consumed directly or indirectly in the form of livestock products, and is thus a useful indicator of consumption patterns. Moreover, data on grain consumption are more widely available and more reliable than that on all foodstuffs considered collectively.

In the poorer countries, the average person can get only about 400 pounds of grain per year—about a pound per day. When only this much grain is available, nearly all of it must be consumed directly to meet minimal energy needs. But as incomes rise so do grain consumption levels. In the wealthier industrial societies, the average person consumes four-fifths of a ton of grain per year. Of this, only 200-300 pounds is eaten directly as bread, pastries, and breakfast cereals. Most is consumed indirectly as meat, milk, and eggs.

In effect, wealth enables individuals to move up the biological food chain. Thus, the average Russian or American uses roughly five times the land, water, and fertilizer used by an Indian, a Colombian, or a Nigerian. This ratio is not likely to widen appreciably. The lower limit on consumption is established by the survival level and the upper limit by the physical capacity of the human stomach to consume animal protein.

The dominant change in dietary habits since mid-century has been the dramatic increase in consumption of livestock products among the affluent in both rich and poor countries. This trend has been most pronounced in the United States, where consumption of some livestock products has more than doubled over the past generation. In the northern tier of industrial countries—stretching eastward from Britain and Ireland and including Scandinavia, Western Europe, Eastern Europe, the Soviet Union, and Japan—dietary patterns compare roughly with those of the United States a generation ago. Rising income in these countries has generated additional demand for livestock products, but few nations can meet this growth in demand using only indigenous resources. Most must instead rely at least partly upon imported livestock products or else import feedgrains and soybeans to produce them. In 1975, roughly one-third of the world's grain harvest—some 400 million tons—was being fed to livestock and poultry. The net effect of such growth in the demand for food, wherever it originates, is growing pressure on the earth's land and water resources.

## LAND AND WATER

Until about 1950, the expansion of the area under cultivation accounted for most of the growth in the world's food supply. Since then the stork has outrun the plow. The growth in cultivated area has slowed markedly while continuing growth in the food supply has come largely from raising land productivity. As the human population has grown, the amount of cropland per person has declined: today there is less than one acre for each of the earth's four billion inhabitants. Barring discovery of a cheap way of irrigating the deserts, croplands are not likely to expand substantially.

Crop cultivation has spread from valley to valley and eventually from continent to continent, until today some 3.3 billion acres, or roughly 11 percent of the earth's land surface is under cultivation. Yet, in some southern European and African countries, the area under cultivation is actually declining as soil erosion leads to the abandonment of marginal cropland, as cropland is converted to non-farm uses, or as deserts encroach.

When the total area under cultivation is expressed as a share of the earth's surface, it seems rather small; but as a percentage of the land capable of supporting productive vegetation, it is quite large. Most of the earth's land surface is too dry or too cold to support plant life. Deserts cover much of the African continent and large portions of Asia. The interior of Australia is largely desert wasteland; and large arid areas also exist in southern Europe, on the western coast of Latin

America, in northeastern Brazil, and in the southwestern United States. Where rainfall is not a limiting factor, location, elevation, or climate may be; the Rocky mountains, the Andes, the Alps, and the Himalayas will probably never support commercial crops.

Estimates of how much additional land can be brought under the plow are plentiful, but most are not very useful because they fail to specify at what cost the additional land could be made productive. Meaningful estimates must take into account the relationship between the cost of the food that could be produced to what people could afford to pay.

Most good cropland is already being worked. Little, if any, new farmland awaits the plow in Europe or Asia and relatively little remains in the Soviet Union. Most North African and Middle Eastern countries cannot significantly expand the area in crops without developing new sources of irrigation water. The only remaining regions with well watered, potentially arable land yet to be exploited are the tsetse fly belt of sub-Saharan Africa, the southern Sudan, and the vast interior of Brazil, but it would be a serious error to view Africa and Brazil as vast unexploited repositories of fertile farmland. Much "potentially cultivable" land lies in the tropics, and the problems of farming tropical soils on a sustained basis are myriad. A critical key to opening large new areas to agriculture in sub-Saharan Africa is eradication of the tsetse fly, which carries the cattle-killing disease trypanosomiasis. In the Sudan and Brazil, heavy investments in roads, marketing systems, credit institutions, and technical advisory services are needed before the new land can be brought into use.

While unexploited fertile land is scarce, the lack of fresh water may be an even more severe constraint on efforts to expand world food output. In Green Revolution countries as widely separated as Mexico and Afghanistan, a shortage of fresh water is the main constraint on the area planted to the high-yielding wheats. In the Soviet Union, a lack of fresh water is frustrating efforts to expand feedgrain production for the swelling livestock herds.

Competition for water among countries with common river systems has become increasingly intense. Protracted negotiations were required to allocate the waters of the Indus River between India and Pakistan. Without the mediating role of the World Bank, the irrigation potential of this river system might never have been realized at all. Conflicts over water rights and usage of the Ganges emerged in 1976 between India and Bangladesh. Competition is also keen between Israel and the Arab countries for the waters of the Jordan. Difficult negotiations were required to allocate the Nile River waters between Sudan and the United Arab Republic. The distribution and pollution of the Colorado River water are a continuing irritant to U.S.-Mexican relations.

As new possibilities for irrigation diminish, the link between bread and water becomes increasingly obvious. Irrigation has played a major role in expanding the earth's food-producing capacities. Irrigated, not rainfed, agriculture provided the surplus food and the impetus for social organization so critical to the earliest civilizations in Mesopotamia and Egypt. Controlling the turbulent and often dangerous Tigris and Euphrates Rivers was no easy task; their floods are unpredictable and can be violent. By contrast, the flood of the Nile is comparatively gentle, punctual, and ideally synchronized with the actual growing season. These characteristics led Herodotus to describe Egypt as the "gift of the Nile." Irrigation also developed early along the major rivers of southern Asia, particularly along the Indus and the Hwang Ho, or Yellow River of China.

Although man practiced irrigated agriculture as much as six thousand years ago, it was not until the twentieth century that irrigation began to cover a significant share of the earth's land surface. In 1800, an estimated 20 million acres of the world's cropland was irrigated. By 1900, this had expanded to 100 million acres, and by 1950, to 260 million acres. But the greatest expansion has occurred since 1950 with the irrigated area nearly doubling to an estimated 500 million acres in 1975. In China alone, the number of irrigated acres has increased by more than 60 million since 1950 and now exceeds a hundred million. This vast construction effort has been achieved largely through the massive mobilization of abundant rural labor.

As pressures to produce ever more food intensify, national governments are being forced to consider ambitious interventions in the hydrological cycle. They are considering, among other tactics, rainmaking through cloud seeding and the wholesale diversion of rivers. In order to augment the supply of irrigation water in the southern part of the country, the Soviet leadership is planning to reverse the flow of four Arctic-bound rivers by blocking their northward pasasge and constructing diversion channels.

During the mid-sixties public attention focussed on the potential for desalting sea water as a means of expanding irrigation supplies. Proposals surfaced for massive nuclear powered agro-industrial complexes. Like many other dreams based on dramatic new technologies this one too has faded. Hoped-for improvements in desalting technology have yet to materialize and rising energy costs make the use of desalted sea water for agricultural purposes particularly costly.

Future water requirements for agriculture are large and growing. Like per capita grain requirements, they escalate as diets improve. A person subsisting on a vegetarian diet of 2.5 pounds of grain a day is indirectly utilizing 300 gallons of water daily. Production of food for an affluent diet of 2 pounds of vegetable matter and 1 pound of beef and animal fat a day requires a total of 2,500 gallons of water daily. The "water cost" of a pound of beef, which includes that used to produce grass and feed as well as that drunk by the animal, is about 25 times that needed to produce a pound of bread.

TABLE 1: ESTIMATED WORLD IRRIGATED AREA, 1900-2000

| Year | Estimated Irrigated Area (million acres) | Annual Rate of Increase (percent) |
|---|---|---|
| 1900 | 100 | 1.9 |
| 1950 | 260 | 2.9 |
| 1970 | 460 | 1.1 |
| 2000 | 640 | |

Sources: FAO, Production Yearbook (various issues) and author's estimates.

The prospect of feeding the future population adequately is pinned to the prospect of expanding the area irrigated by large-scale river systems, a prospect that appears much less favorable in the final quarter of this century than in the one just ended. The easiest-to-build of massive irrigation projects, whether in China, India, the Soviet Union, the Middle East, Africa, or North America have already been completed. The ready irrigation potential of most of the world's major rivers, including the Nile, the Yellow, the Indus, the Ganges, and the Colorado has largely been realized. Among those not yet exploited are the Mekong and the Amazon, but the latter's vast width and broad flood plains make it virtually impossible to harness. Thus, while the world irrigated area expanded by nearly 3 percent annually between 1950 and 1970, it will probably grow at barely 1 percent a year for the remainder of this century.

## FOOD: THE ENERGY DIMENSION

The production of food requires energy other than that supplied directly by the sun. In early agricultural systems, the principal energy input—aside from solar energy—was that expended by man himself in producing food. Over time humans have devised ways to use other sources of energy to expand the food supply. Domesticating herbivores as a means of converting roughage into meat and milk was one. The harnessing of these same animals as a means of converting roughage into a form of energy that man could use to expand food supplies was another.

Yet, not until the much more recent arrival of the internal combustion engine could fossil fuels be harnessed extensively for tillage. The advent of chemical fertilizers, particularly nitrogen, brought another massive jump in the use of energy to produce food. The artificial fixing of atmospheric nitrogen in chemical form now takes place on a scale rivaling that of nature itself; while nature fixes an estimated 120 million tons of atmospheric nitrogen through legumes, soil microflora, and lightning each year, man now adds some 40 million tons of nitrogen to the soil in the form of nitrogen fertilizer.

The three basic types of agriculture are built around three kinds of energy imputs. The simplest, one that relies on human muscle power alone, is still practiced in some parts of the world. It is best exemplified by Mexican hoe-corn cultivation or the more primitive forms of wet rice cultivation that involve little more than hand sowing and hand harvesting. The second, which utilizes draft animals as the principal source of energy, prevailed worldwide until World War II and still prevails in Asia, Africa, and Latin America. The third system is highly energy intensive and relies heavily on the internal combustion engine and where appropriate chemical fertilizer and irrigation. Somewhat over half of all world agriculture is of this type.

Energy is used in agriculture to raise the productivity of both labor and land. In the United States, Canada, Australia, and in other countries where land has been relatively abundant and labor relatively scarce, energy has gradually been substituted for labor through large-scale mechanization. Only over the last generation or so, has energy been intensively employed to raise land productivity. In Japan and China, where land has been historically scarce and labor relatively abundant, the primary emphasis has been on raising land productivity through the intensive use of labor and energy.

As the global demand for food expanded far more rapidly than the cultivated area, more and more energy was required to raise land productivity. From 1950 until oil prices rose sharply in 1973, the world's farmers substituted energy for land with a free hand.

The two-thirds growth in world population of two-thirds since mid-century was made possible by increases in food output that were in turn made possible by cheap energy. Rising energy costs in a world where the principal techniques available for expanding food production (such as chemical fertilizer and irrigation) are energy-intensive does not bode well. In the midwestern corn belt of the United States, the energy embodied in the nitrogen fertilizer used on corn exceeds the fuel used in tractors during plowing, planting, cultivation, and harvesting. If agriculture's energy supply is threatened, the population that depends upon it will be too.

Opportunities for conserving energy in modern food systems are myriad, but few of them exist in the farm sector. Most of the energy that is needlessly squandered in the food system is wasted in food distribution, not in food production. Only one-fourth of the energy used in the ultra-modern U.S. food system, for example, is used for production. The remaining three-fourths is spent to transport, process, and package the food once it leaves the farm. Commonly, the aluminum foil in which food is often wrapped embodies more energy than does the food itself. One of the grossest and yet most subtle inefficiencies in the food system is the use of a two-ton automobile to transport 25 or 30 pounds of groceries from the supermarket to the home.

The farther people live from their food supply, the more energy is required for food transport and processing. Indeed, the massive urbanization that has taken place since mid-century depended heavily on cheap energy; and as energy becomes scarcer and costlier, urbanization will slow or perhaps even reverse itself.

## THE GREEN REVOLUTION

The term "Green Revolution" describes in shorthand the introduction and spread of high-yielding dwarf wheats and rices in the developing countries. The high-yielding wheats were developed in Mexico by a team of agricultural scientists from the Rockefeller Foundation. They first evolved in Japan and were introduced into Mexico via the northwestern United States where they had increased wheat production dramatically in the irrigated wheat growing areas of the Northwest.

The defining characteristic of the high-yielding seeds was their responsiveness to fertilizer. Heavy doses of fertilizer on tall, thin strawed indigenous varieties of wheat and rice often lodged (fell over). The sturdy dwarf wheats and rices raised the optimum level of fertilizer use from roughly 40 pounds per acre to 120 pounds. Well-managed, dwarf varieties can yield twice as much wheat per acre as regular strains can. Adapted to a wide range of growing conditions, the new wheats, with the associated inputs and cultural practices, represented a packaging of the intensive cultivation which had evolved earlier in the agriculturally advanced countries.

Encouraged by the adaptability of the new wheat varieties, the Rockefeller and Ford Foundations joined forces in 1962 to establish the International Rice Research Institute (IRRI) at Los Baños in the Philippines. Within years, research using dwarf genes from Japan led to the development of high-yielding rice varieties that were then quickly distributed throughout Asia.

Not only highly responsive to fertilizer, the new varieties also make more efficient use than traditional varieties of land, water, and labor. Instead of yielding 5 to 10 pounds of additional grain per pound of fertilizer used, they yield up to 20 additional pounds per acre. On a given area of land, properly managed new varieties could easily double production while increasing by a third or more the productivity of water and labor used in agriculture.

Appearing at a time when food deficits in the poor countries were widening and when requests for food aid were pouring into Washington, the high-yielding grains were widely heralded. To be sure, their spread across national borders represented one of the most unique and successful efforts to disseminate a new technology on record. In 1964-65 the area planted to the high-yielding wheats and rices in Asia totaled some 200 acres, mostly experimental demonstration plots. Four years later, 34 million acres had been planted with the new seeds. If output increased by roughly a half ton per acre, the Asian food supply increased by 17 million tons, or enough to feed more than 100 million people.

When the Rockefeller team arrived in Mexico in late 1944, it was a hungry country importing much of its food from the United States. By 1967, less than a quarter century later, wheat production had tripled, corn production had doubled, and the average Mexican was consuming 40 percent more food. Both wheat and corn were being exported and the economy was prospering.

Advances in Asia were in some cases even more dramatic than Mexico's. India doubled its wheat crop in one six-year-period, a feat unmatched by any large country for a principal



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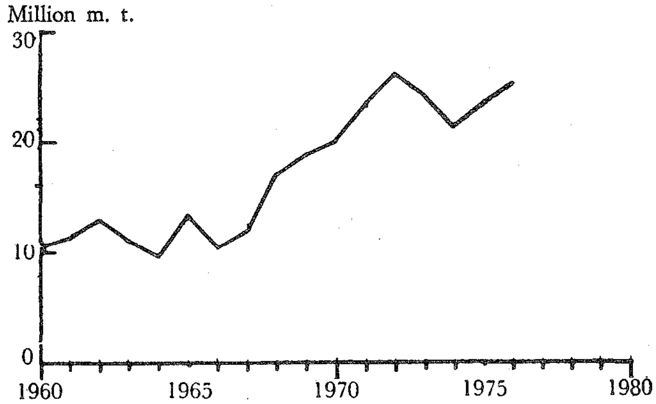


Fig. 2: India: Wheat Production, 1960-76.

staple. In Pakistan, the advances in wheat production were only slightly slower. While far less dramatic, rice production gains were substantial, particularly in the Philippines, Sri Lanka, Indonesia, and Malaysia.

The Green Revolution enabled many countries to cut back grain imports and enabled some to become exporters. India, riding the crest of the Green Revolution, was on the verge of cereal self-sufficiency in the early seventies. Mrs. Gandhi proudly proclaimed that India was no longer dependent on U.S. food assistance. Advances in rice production in the Philippines ended, at least temporarily, a half century of dependence on imported rice.

Food production advances in the Green Revolution countries continue at a slower rate. Wheat production has expanded most rapidly, while the spread of the high-yielding rices depends on investments in sophisticated irrigation and water control—a capital-consuming, time-consuming requirement. Yet, the initial quantum jumps associated with the Green Revolution are largely past. Those who were involved in the launching of the Green Revolution, such as Dr. Norman Borlaug, who



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received the Nobel Peace Prize for his work with the high-yielding wheats, had warned from the beginning that the Green Revolution was not a panacea, not a solution to the world food problem. At most, they said, it would only buy time, perhaps 10 or 15 or 20 years during which governments could bring population growth under control.

Governments could take one or two basic views of the Green Revolution. They could see it as a means of buying time with which to expand family planning services, or they could see it is a means of postponing some of the difficult decisions in population policy. Regrettably, most took the latter view, few the long one. Consequently, a full decade has passed since the international launching of the Green Revolution and population is outrunning food supply in country after country. As of the mid-seventies, the Green Revolution's homeland, Mexico, is again importing a large share of the grain it needs. (See figure 3). India, too, has been forced to buy large quantities of grain on foreign markets, while the Philippines now imports more grain than it ever had before.

Only China, which is seldom considered a Green Revolution country, has incorporated Green Revolution principles (namely, the use of fertilizer-responsive, dwarf varieties) without back-sliding once great productions have been realized. China is an exception because the government's foresight was exceptional: even while the nation was making handsome gains in grain output, it was also launching an ambitious family planning effort. Having cut its population growth rate in half over the past decade, China is now expanding its food production far more rapidly than its population.

## DECLINING LAND PRODUCTIVITY

The ancients calculated yield as the ratio of grain produced to seed planted. For them, the constraining factor was seed-grain itself. The yield was probably very low, reflecting the marginal nature of early agricultural ventures. Today, wheat grown in the Great Plains yields 30 pounds for each pound used as seed. For rice grown using the intensive Japanese

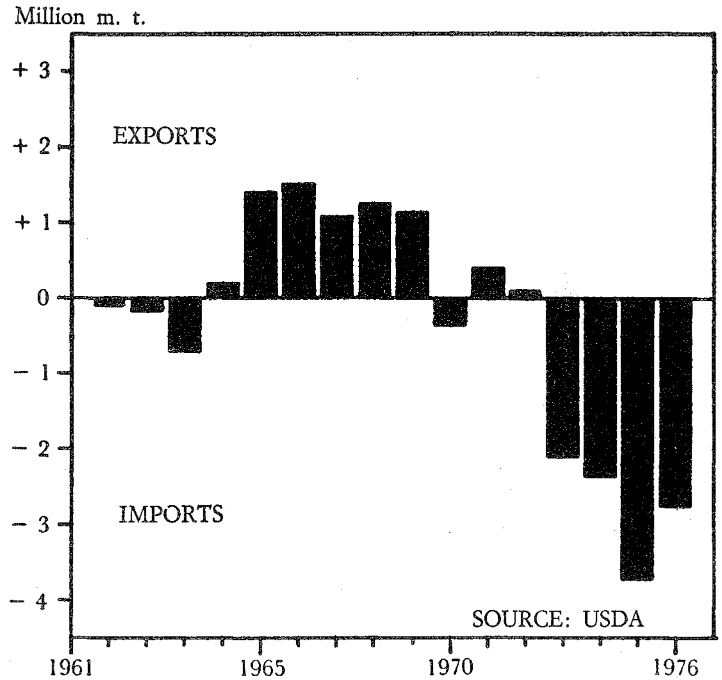


Fig. 3: Mexico. Net Grain Trade, 1961-76.

paddy technique of transplanting, the ration may be 300 to 1. For corn, the only cereal domesticated in the New World, the ratio often reaches 500 to 1. Believed to be the last of the three major cereals to be domesticated, maize is in one sense the most productive.

As agriculture spread and as more and more of the world's potentially tillable land was brought under cultivation, the focus shifted from the productivity of seed to that of land. Using yield per hectare as the principal criterion, corn remains at the top of the list. The U.S. corn yield, exceeding six tons per hectare, surpasses even the Japanese rice yield. Within the United States, the per acre yield of corn easily quadruples that of wheat, a cereal grown largely under semi-arid conditions. Wheat yields are also low in other semi-arid wheat growing areas such as those in Canada, the Soviet Union, North Africa, the Middle East and Australia.

From the end of World War II until the early seventies, the productivity of cropland moved rather steadily upward. Between 1960 and 1972, the average worldwide grain yield per hectare increased from just under 1.38 tons per hectare to 1.91 tons per hectare. Since then, however, yields have dropped averaging only 1.84 tons in 1976.

Since little new cropland is now available, this downturn in yield per hectare has hit the world food economy hard, contributing to food scarcity and rising food prices. The fall-off appears to be the product of several factors. The marginal quality of the land that has recently been brought under cultivation (including importantly the 50 million acres of U.S. idled cropland) is one.

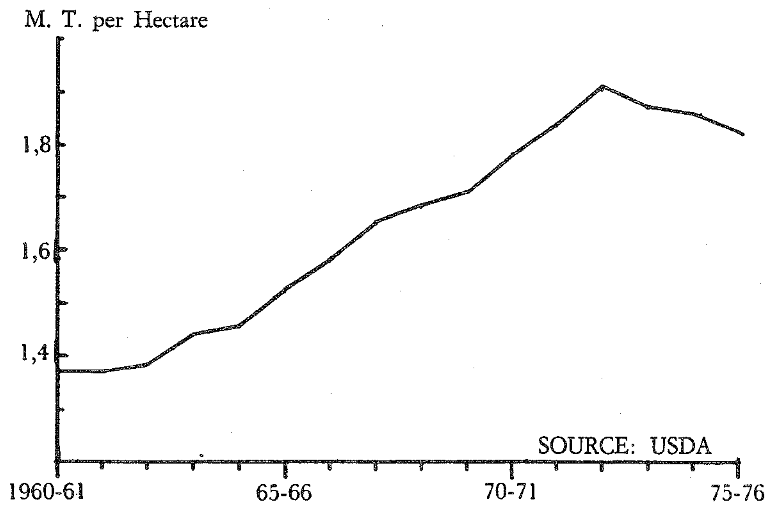


Fig. 4: World Grain Yield Per Hectare.



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Another is the high cost of energy. The sixfold increase in the cost of petroleum during the seventies has reduced agricultural energy use below what it otherwise would have been. A third and closely related factor is the high cost of fertilizer. Fertilizer prices during the mid-seventies, influenced in part by rising energy costs, have soared to record highs.

A fourth factor influencing the productivity of cropland is a shrinkage in the world's fallowed area. Land is usually fallowed either to accumulate soil moisture or to replenish soil nutrients. In wheat-growing areas where the rainfall may not be adequate to sustain continuous cultivation, farmers have adopted a system of alternate year cropping: the land is planted in wheat one year and then left fallow and kept clean from vegetation the next. Fallowing permits the soil to accumulate moisture and helps ensure a good harvest the following year. In the Western Great Plains of the United States, strip cropping performs this function; planting alternate strips minimizes wind erosion on the bare bands. As world wheat prices rose during the seventies, the amount of land in fallow has declined from an average of 65 acres for every 100 acres planted in wheat during the sixties to 37 acres in 1976. As a result, U.S. wheat yields have fallen, and severe dust storms reminiscent of the thirties are reappearing in some states.

In tropical and sub-tropical regions, land can often be cropped for only a few years before the soil structure deteriorates and nutrients are depleted. Under these conditions a type of shifting cultivation has evolved where farmers clear land of forest cover, usually by burning, cultivate it for a few years, and then abandon it as fertility drops. After the twenty to twenty-five years the soil requires to restore its nutrients, farmers then return to clear and cultivate the land again. This method worked quite well until population pressures in the tropics forced shifting cultivators to shorten the rotation cycles. As cycles are shortened, productivity falls, as it has in a number of countries such as in Nigeria, the most populous country in Africa. (See figure 5).

Still another negative influence on yields is the deterioration in soil structure and fertility associated with the spreading firewood crisis in developing countries. When firewood con-



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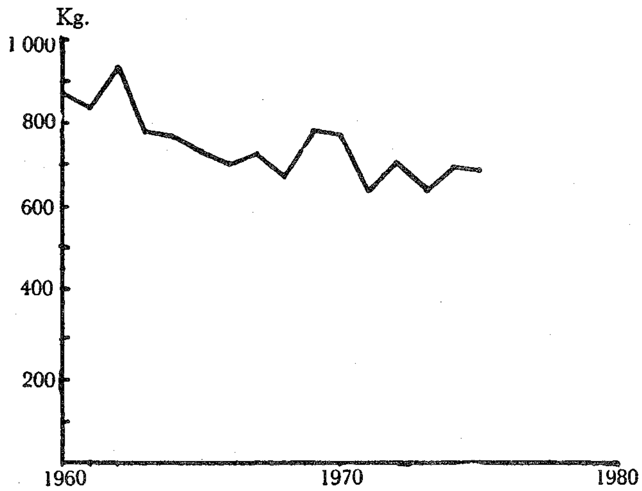


Fig. 5: Nigeria. Coarse Grain Yield per Hectare, 1960-75.

sumption leads to deforestation it may adversely affect food production in two ways. As the forests disappear soil erosion accelerates. Additionally, villagers unable to obtain firewood burn animal dung instead, thus depriving the soil of needed nutrients and organic matter.

Increasing population pressures, deforestation, and the farming of marginal soils—all take their toll on the topsoil on which agriculture depends. And the loss of just one inch of topsoil in, for example, the U.S. corn belt (where the topsoil base is about nine inches deep) can reduce the corn yield by an estimated 4.5 bushels per acre.

While the world demand for food expands at a record rate, the difficulties of raising or, in some situations, even maintaining soil fertility are multiplying. Only by applying ever larger amounts of fertilizer can many farmers maintain the fertility of their soils. As energy becomes more costly, so too will fertilizer.

THE PROTEIN BIND

The two basic yardsticks for measuring the quality of diets are calories and protein. Calories measure the diet quantitatively, protein qualitatively. The several hundred million people who are chronically undernourished suffer from a shortage of calories or protein or both. Since expanding protein supplies at an adequate rate has become increasingly difficult during the seventies, protein hunger could well worsen in the years ahead.

Three protein sources dominate the world protein economy —fish, beef, and soybeans. The first two are the product of natural systems, fisheries and grasslands, both of which are under stress.

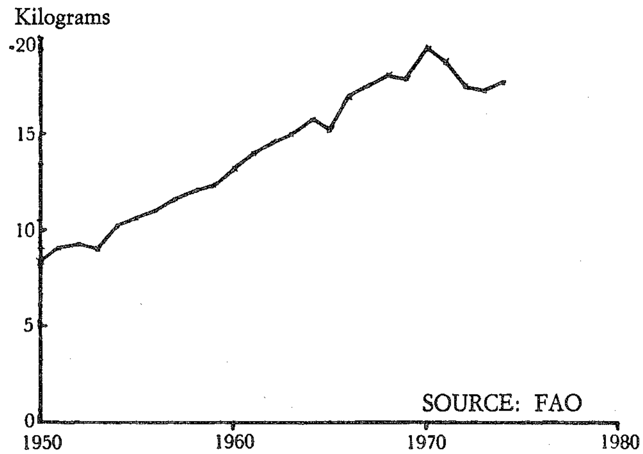


Fig. 6: World Fish Catch Per Capita, 1950-74.

According to some marine biologists, the catch of table grade species cannot be measurably expanded beyond current levels; expanding marine protein, they say, means descending the food chain to eat inferior species. Similarly, extracting more and more beef from the world cattle herd (which now produces



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yearly some 40 million tons or 22 pounds per person) has already led to overgrazing and the deterioration of grasslands in some countries. Moreover, improving the efficiency and productivity of livestock operations is difficult since most of the world's grazing areas are natural or unimproved grasslands in semi-arid regions.

Other important biological constraints impede protein production and beef production in particular. Like the first domesticated cattle, beef cows still produce only one calf each year. And since not every cow bears a calf each year even in the best managed herds, the calving rate drops far below 100 percent. Thus, for every calf that goes into the market cycle one cow must be maintained for one full year. Herds could, of course, be sharply expanded if more cattle could be put in feedlots; but cattle in feedlots compete directly with human beings for grain. More likely, market forces will reduce the amount of grain fed to cattle if grain prices continue to rise.

The third principal source of high-quality protein is soybeans, a crop produced almost entirely by three countries—the United States, Brazil, and China, where the crop originated. Between 1950 and 1975, the world soybean harvest expanded from 16 to 61 million tons. The Chinese harvest fluctuated around 9 million tons, showing no particular trend either up or down. The expansion of soybean production occurred mostly in the United States; with a 1976 harvest of 41 million tons, it now reaps two-thirds of the world harvest. Since soybean prices doubled in 1974, Brazil has been dramatically expanding its acreage from a small base, edging ahead of China in 1976.

None of the three soybean producing countries has been able to achieve a breakthrough in soybean yield per hectare. Attempts to raise soybean yields run up against incontrovertible biological facts: legumes fix their own nitrogen and respond only modestly to applications of nitrogen fertilizer. Yields have edged upward only grudgingly. U.S. soybean yields have increased by a mere 25 percent since 1950, while corn yields nearly tripled during that time.

In effect, farmers get more soybeans only by planting more soybeans. From 1950 to 1973, U.S. soybean acreage moved to a new high virtually every year, expanding from 16 million



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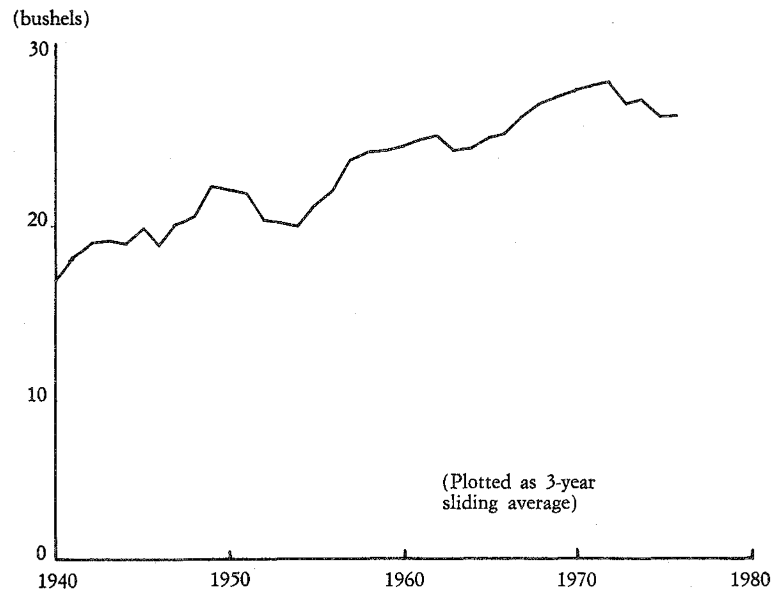


Fig. 7: United States. Soybean Yield Per Acre, 1940-76.

acres to 55 million acres (figure 8). In 1973, this era of rapid continuous expansion in soybean acreage and supplies ceased, largely because the idled cropland had vanished. Future gains in acreage will likely come only at the expense of other crops.

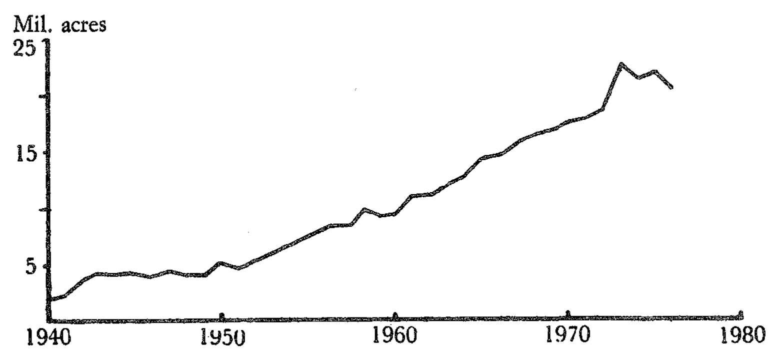


Fig. 8: United States. Soybean Area Harvested, 1940-76.



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With one acre in every six on U.S. farms now planted in soybeans, how much more land can farmers convert to soybean production and still satisfy the expanding world demand for other crops? In many parts of the country, soybeans must compete with corn, the yields of which have been rising dramatically.

While the United States cannot continue to expand soybean acreage as it did from 1950 to 1973, Brazil still has a substantial opportunity for expansion. In Brazil, soybeans and cereals, particularly wheat, have proved to be more complementary and less competitive than in the United States. In southern Brazil, soybeans, a summer crop, are successfully rotated with wheat, a winter crop. Consequently, Brazil can produce two harvests per year. As a bonus, the soybeans fix nitrogen that helps to produce the wheat crop.

Unfortunately, in parts of Brazil soybeans do compete with table beans. The surging demand for Brazilian soybeans as livestock feed in affluent Europe, the Soviet Union, and Japan, is drawing land away from Brazilian table beans and increasing their price. This in turn aggravates protein hunger among low income Brazilians for whom they are a food staple. In order to maintain and expand soybean production, the Brazilian Government has set the farm support price for soybeans at $5.00 per bushel, well above the estimated production cost of $4.50 per bushel. Any substantial expansion of soybean production will thus probably not occur at much less than $5.00 per bushel. In short, cheap soybeans are probably a luxury of the past.

Given the difficulties in expanding the world supply of high quality protein—fish, meat, or soybeans—strong upward pressure on protein prices seems likely to continue. Indeed, soybean prices tripled during the seventies. If the price of soybeans, perhaps the best single indicator of the tightening world protein supply, continues to rise, reducing protein hunger may be even more difficult than it has been in the past.

TECHNOLOGY ON THE DRAWING BOARD

The thirty-year-span from 1940 to 1970 was characterized by unprecedented advances in agriculture. New technologies were quickly developed and quickly commercialized; and they contributed to quick gains in farm output. Great strides typified agricultural science, plant genetics, animal nutrition, soil fertility, and farm-equipment design. Agricultural scientists, the majority of whom work for agribusiness firms, made great gains in the fields of animal husbandry and nutrition. Today, some dairy cows are capable of producing more than 40,000 pounds of milk per year, nearly 50 quarts daily. Under optimum conditions, broilers can now add a pound of weight with scarcely two pounds of feed. Some dwarf wheats can now double wheat yields virtually anywhere wheat will grow if fertilizer and water are abundant.

This three-decade-span was a rich and fruitful one for agricultural science, a period in which scientific principles and knowledge were converted into production technologies on a record scale. Work done in soil science and plant nutrition by German scientist Justus von Liebig in the mid-nineteenth century, which laid the foundation for the chemical fertilizer industry, was finally exploited on a global scale. Knowledge in genetics, which was based on the work of Austrian monk Gregor Mendel, was being put to good use by plant and animal breeders. These and other cumulative scientific advances were being applied on a grand scale. Yet, as food supplies tightened during the early seventies, confidence in science's power to push back the constraints on food production fast enough to meet growing demands ebbed.

According to agricultural scientist Louis Thompson of Iowa State University, the backlog of unused agricultural technology is shrinking. As recently as 1960, the average corn yield attained by farmers in Iowa was scarcely half that attained by the experiment stations. But since then, yields on the experiment stations have risen only modestly while those attained by Iowa farmers have increased dramatically and have steadily approached the levels attained on the experimental plots.

Food production is a biological process and, like all other



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biological activities, it must eventually conform to the ultimate constraints on biological activity. Whether crop production per hectare or milk production per cow, trends must eventually conform to the "s" shaped growth or logistic curve. Crop production per hectare is ultimately limited by the incidence of solar energy. Forest productivity is limited by the regenerative capacity of the forest under optimum conditions. The efficiency of the conversion of feed into meat by broilers is ultimately limited by the physiology and metabolism of the birds themselves.

Selective breeding and improved nutrition of both plants and animals can push up production limits—but only to a point. Some of these limits are already being approached in some situations. Sorghum yields and milk production per cow in the United States and rice yields in Japan exemplify the

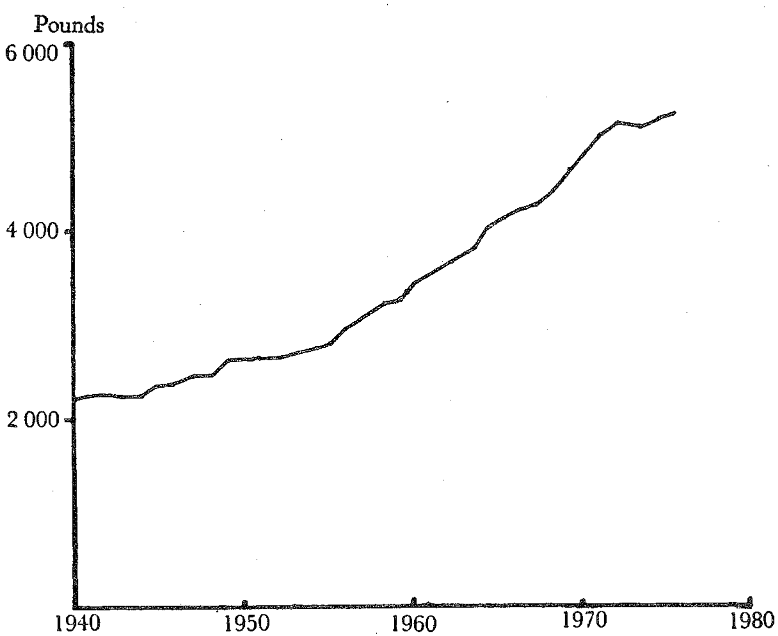


Fig. 9: United States. Milk Production per Cow.



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fact that growth in yields has passed the inflection point on the "s" shaped curve and is beginning to slow, if not stabilize. Corn yields in the United States and wheat yields in Western Europe may also have passed the inflection point on the logistical curve.

The conditions under which the world's farmers and fishermen will attempt to expand food output during the final quarter of this century are less favorable than in the past. The question is not whether the world can expand food production but at what cost it can do so. And, importantly, how does the cost relate to the purchasing power of the world's poor.

The seventies have witnessed two ominous and disturbing reversals in the world food economy. One has been the downturn in land productivity, the other the downturn in per capita food consumption. Even though the former is virtually certain to regain its upward thrust, the prospect for the latter is much less clear. From 1950 to the early seventies, food production per person in the world edged upward in a steady and rather predictable fashion. Consumers and governments were optimistic. But average consumption levels have fallen since 1972; and for those for whom consumption was just beginning to meet nutritional requirements, this reversal has been a crushing blow. Because food is primarily apportioned through purchasing power, a disproportionate share of the reduction has fallen on the world's poor.

A world of cheap food with stable prices, surplus stocks and a large reserve of idled cropland may now be history. Barring some dramatic gains in the priority given family planning and food production, the present augurs a somewhat grimmer future, one of more or less chronic scarcity enlivened only by sporadic surpluses of a local and short-lived nature. Steadily rising food production costs may make global inflation progressively less manageable, and the international community's failure to respond effectively to crop shortfalls in poor countries may lead to increasing nutritional stress and climbing death rates.

Progress in eliminating hunger and malnutrition is not likely without a more equitable distribution of available food supplies both within and among societies. As the demand for agricultural resources in other sectors grows, priorities will have to be established between the use of land, water and energy for food production and for other purposes. In a world where scarcity becomes commonplace and where food remains basic not only to human survival but also to economic and political stability, family planning and agriculture must be accorded a far higher priority.



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