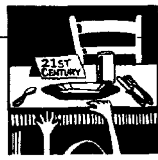

Conserving Habitat, Feeding Humanity

Technology, economic growth, and trade are key to feeding the world while leaving room for the rest of nature.

BY INDUR M. GOKLANY

Two centuries have passed since English economist Thomas Malthus penned his seminal essay on population. At the time, Malthus speculated that population growth would eventually outstrip humanity's ability to produce an adequate supply of food.[1]

Since Malthus' day, the global population has increased sixfold, from under 1 billion to 5.9 billion. The average person today, however—especially in the developed world—not only devotes less time and effort toiling to put food on the table but, more important, is better fed, is healthier, and lives longer than his or her ancestors of 200 years ago. In fact, late 20th century Englishmen are on average nearly three inches taller and live twice as long as Malthus' 18th century compatriots.[2]

The availability and quality of food has increased not only in the developed world but in the developing world as well. Since 1950, for example, in both China and on the Indian subcontinent, average per-capita food consumption—in terms of calorie intake—has increased about 30 percent and 45 percent, respectively. Together, these two regions comprise more than 40 percent of the world's population.[3]

In addition, by one estimate, the number of people facing famine during the post-World War II era dropped by 95 percent, from more than 700 million in 1955 to 35 million in 1992, despite a virtual doubling of global population from 2.8 to 5.5 billion.[4] And, remarkably, despite increases in both population and per-capita food demand, international food commodity prices declined nearly 80 percent between 1950 and 1992.[5]

Yet, Malthus' question persists: as the world's population doubles during the next century, is it possible that our food resources eventually will fail to sustain that population? Will we run out of land and water to meet our food needs? And even if we don't, will we squeeze out the rest of nature in that quest?

Technology to the Rescue

The key to understanding our prospects for feeding the world's population lies in learning from the past, understanding why the Malthusian vision has not yet come to pass, and applying those lessons to the future.

Between 1800 and 1992, the global population increased 5.5-fold while cropland increased only 3.5-fold, from about 1 billion acres (400 million hectares) to 3.5 billion acres (1.4 billion hectares).[6]

Clearly, during the past two centuries, we have successfully produced more food from a given amount of land—that is, we have learned to use our land more productively. How have we achieved this goal? Part of the answer lies in greater use of old, as well as advanced, technologies.

Consider, for instance, that in 1700, feeding one person required about 1 acre (0.4 hectare). That amount peaked at about 1.2 acres (0.5 hectare) per person in 1920. Since then, the amount of land needed to feed one person has declined about 50 percent, to 0.6 acre (0.25 hectare). Put another way, over the past three-quarters of a century, technological changes have given us the ability to feed twice as many people on a given amount of land.

Among the more notable technological breakthroughs in agriculture are (1) laboratory-bred, high-yielding crop varieties that mature faster, making it possible to grow multiple crops in a single growing season; (2) improved livestock-management practices, including artificial insemination, better veterinary medicine, and development of feed supplements; (3) greater, more effective use of fertilizers and pesticides; (4) advances in agricultural machinery and tools; (5) refrigeration, canning, and other means of preserving food and produce, which reduce spoilage and waste; and (6) more-precise methods for forecasting weather.

Floods

At the same time, new applications of the age-old technology of irrigation, which can more than double yields, have been extended to about 20 percent of the world's cropland, compared to only 2 percent of the land in 1800 and just 6 percent in 1950.[7]

An elaborate transportation and distribution infrastructure not only boosts farm production by bringing fertilizers, pesticides, fuels, and other inputs to farms, but it also moves products from producers to markets. Thus, gas-driven vehicles, huge oceanic vessels, and intercontinental jet airplanes—hallmarks of the 20th-century transportation revolution—have helped feed the world more cheaply and efficiently, as well as move people more freely.

Moreover, since 1920, increased crop yields per acre have saved 3 billion acres (1.2 billion hectares) of forest, grasslands, and other habitat from being converted to cropland.[8] In this way, technology has not only produced more food, but it has forestalled massive conversion of habitat and loss of biodiversity.

As potent as these technologies are, their mere existence is not sufficient by itself to sustain high-yield agriculture and a modern food-supply system. Indeed, several additional conditions must apply.

First, a society—and its farmers—must not be so poor that they cannot afford these technologies. Second, society's laws and policies must encourage innovations and reward farmers for assuming the risks involved in adopting them. Third, poverty, which makes food less affordable, must be controlled. And fourth, efforts must be made to help poorer societies and individuals offset the effects of production shortfalls, whether they're caused by droughts, floods, or—as is more often the case —civil strife.[9] Thus, food security in the 21st century may lie as much in policies and institutions that encourage technological change and economic growth as it does in scientific progress.

Trade Offsets Shortages

Trade—both within and among nations—helps globalize food sustainability by allowing one area's shortage to be offset by another's surplus. For instance, if one area grows an abundance of cotton but produces little grain, it can compensate for its shortage and capitalize on its strength by trading with a country weak in cotton and rich in grain. Equally important, trade reduces, if not eliminates, the need for each nation to be self-sufficient in food. Such self-sufficiency often comes at the cost of ruinous and self-defeating subsidies.

Trade within and among nations also helps reduce the cultivation of marginal lands by allowing a nation to overcome its food shortfalls by importing produce rather than attempting to grow crops on lands that are poorly suited to agriculture. In this way, trade provides an environmental bonus.

For example, cultivated land in the northeastern United States declined by nearly 60 percent between 1949 and 1987, owing primarily to regional and international trade. America's breadbasket in the Midwest allowed the Northeast to grow less food without jeopardizing the health and well-being of its citizens.

Food Needs to 2050

Future food consumption depends, among other things, on the number of people on Earth and their per-capita wealth. The arithmetic is simple and straightforward. The more people there are, the greater the demand for food. And the wealthier these people are, the greater their purchasing power and thus the greater their food consumption, particularly of meat, eggs, and dairy products. Such trends disproportionately increase the demand for grain because two to seven pounds of grain are required to produce one pound of such products.

According to World Bank projections, the current world population of 5.9 billion will double by 2150, with the low- and high-fertility projections ranging from 9.7 to 12.9 billion. Meanwhile, if the world enters an era of sustained economic growth—as most observers hope and expect—overall per-capita food demand should increase, particularly in developing nations.

Assuming that the World Bank's projection of 9.7 billion people in 2050 is correct and global per-capita food supplies will increase at the same pace as they did between 1970 and 1990, food supplies in 2050 should reach 2.2 times their 1993 level. Can the Earth's food supply stretch that much?

Modern-Day Malthusians

Such modern-day Malthusians as Paul Ehrlich, Lester Brown, and David Pimentel suggest that not only will we fail to sustain such a level of food demand, but that, in fact, the Earth's carrying capacity has already been exceeded. For instance, Ehrlich estimates the world's carrying capacity at between 2.5 billion people (on meat-eating diets) and 6 billion people (on vegetarian diets).[10]

In general, these critics contend that the technological factors responsible for the phenomenal growth in the world's food supply since 1950 have topped out and cannot be sustained into the future.[11] Specifically, these neo-Malthusians insist that:

- Past improvements in yield were due, in large measure, to greater use of fertilizers and pesticides, and we are now at a point of diminishing returns for these chemicals.
- We will need ever-more powerful pesticides as insects adapt to existing chemicals. Such applications pose ever-greater risks to the environment and public health.
- Past increases in yield have come at the expense of future productivity. Intensive farming practices, for instance, have increased soil erosion and even led to desertification in arid environments.
- Future productivity will decline because of mounting air pollution, acid rain, ultraviolet radiation, and the prospect of climate change.
- A dwindling amount of arable land is available to be brought under cultivation. Sea-level rise resulting from climate change and increased urbanization will further reduce land available for agriculture.
- Irrigation cannot be significantly expanded. The sites most likely to benefit from irrigation are already in use, and new ones will be economically and environmentally costly. Moreover, silting, salinization, and waterlogging—all consequences of irrigation—will ultimately reduce the effectiveness of existing irrigation systems.
- Many areas of the world lack sufficient fresh water to meet the future needs of agriculture and other competing demands.

There are, of course, alternative visions of the future. Other, more positive projections—for example, by Roger Revelle and Vaclav Smil—suggest that Earth has the capacity to feed between 10 billion and 40 billion people.[12] This variance is due, in large part, to differing assumptions regarding yields, potential crop areas, per-capita dietary requirements, and pre- and post-harvest losses.

Smil, for instance, suggests that Earth boasts the potential for feeding as many as 11 billion people, even without any new technological breakthroughs. Rising demand for food would be met by increasing cropland by about 750 million acres (300 million hectares), optimizing existing technologies, and reducing consumption of beef while increasing consumption of vegetables and grains.[13]

Resolving the differences between the grim prognostications of the neo-Malthusians and the more upbeat projections of other researchers may boil down to three issues. The first issue involves whether we can conserve—or even increase—the existing cropland's long-term productivity. The second depends on whether there are suitable lands available for conversion to cropland. And the third turns on whether there is sufficient water to meet future agricultural and other demands.

New Farming Practices

Though soil erosion, salinization, and water logging currently threaten productive farmland, technologies are already on hand for mitigating those problems.[14] For example, the control of erosion involves maintaining vegetative cover or managing the slope of the land while using such time-tested tillage practices as contour plowing, which protects soil surfaces.

Furthermore, mulching around plants conserves soil moisture and organic matter, and crop rotation interspersed with legume planting reduces runoff and fixes nitrogen. Use of such technologies cut erosion rates on U.S. cropland by about 25 percent between 1982 and 1992.[15]

Meanwhile, the effects of salinization can be mitigated by selecting appropriate salt-tolerant crops—for example, planting wheat instead of corn or rice. Likewise, well-maintained drainage systems, which often can be designed and built at moderate costs, could reduce waterlogging of soil.

Cropland and Water

According to the federal government's 1992 National Resources Inventory, the United States boasts nearly 800 million acres (300 million hectares) that could, if necessary, support crop cultivation.[16] To be productive, some of this land may require special conservation practices, careful choice of crops, or intensive management.

These estimates compare with 240 million acres (nearly 100 million hectares) in the United States that were cultivated in 1990 to meet domestic needs. Clearly, the United States has ample potential cropland to meet its food needs, even if the population and the amount of developed land were to double.

Worldwide, there are at least 8.2 billion acres (3.3 billion hectares) capable of supporting agriculture. That amount is more than double the 3.6 billion acres (1.4 billion hectares) that were planted or available for cropping in 1993.[17]

Though the collective amount of available land is considerable, as much as 60 percent of it is in forests or protected areas. Furthermore, these prospective farmlands may be inherently less productive than existing cropland. In fact, about two-thirds of this surplus cropland is marked by low natural fertility, poor drainage, steep slopes, or sandy and stony soils.

If these marginal lands are to contribute to feeding the world's population, substantial investment will be required, first, to bring them into production and, second, to develop the infrastructure necessary to sustain production. Such infrastructural developments include roads for bringing crops to market and transporting fertilizers and pesticides to farm fields.

Though irrigation can significantly increase yields, residential and industrial demands for water are increasingly taking priority over agricultural use. This trend may be inevitable. As countries become richer, they become more urbanized, and agriculture's share of gross domestic product and total employment shrinks. Thus, the economic and political clout of their agriculture sectors diminishes.

Under such conditions, it will become increasingly difficult to ensure adequate water supplies for farmers if traditional institutions and practices persist. However, numerous opportunities exist for conserving water. In the United States, for instance, 80 percent of the water consumed nationally is used for irrigation. By some estimates, more than half the water diverted for irrigation is wasted.[18]

Therefore, a small increase in irrigation efficiency goes a long way toward meeting water needs of other sectors. Consider, for instance, that increasing irrigation-system efficiency from 41 percent, where it stood in 1975, to nearly 47 percent, where it stood in 1987, saved enough water to meet 80 percent of the increase in domestic consumption.[19]

Treating water as a commodity—that is, establishing realistic prices for it and allowing trading so that unused water could be sold to other users—would give farmers the incentive to conserve water. In the process, it would boost investments and stimulate research in water-conservation technologies and practices, among them the use of drought-tolerant crops and more efficient water-delivery systems.

Successful cases of formal and informal trading have been recorded in socioeconomic milieus as diverse as the United States, Chile, Jordan, and India. These cases indicate that water trading has the potential for making water use more efficient and for providing the incentives to conserve that scarce resource.[20]

Technology Boosts Yields

While new technologies can help the world fill its breadbasket, a number of existing technologies remain underused, particularly in developing countries.

For example, average corn yield of developed countries is 132 percent—and of the highest yielding nation, 285 percent—higher than that of developing nations.[21] Yields achieved by research stations or individual farmers are even higher. At a yield of 8.5 tons per acre (21 tons per hectare) of corn, for instance, the 1992 champion U.S. corn grower achieved a yield more than double the average yield for even the highest yielding nation, Greece.[22] Given that two-thirds of the world's corn acreage is harvested in developing nations, the potential exists for substantially increasing global corn production using existing technologies.

Though modern farming systems have increased the technological limits for yields, there is further room for improvement because theoretical maximum yields are significantly higher.[23] By some estimates, maximum global cereal yield is about 5.4 tons of grain per acre (about 13 tons per hectare). By comparison, the average global cereal yield in 1990 was 1.1 tons per acre (2.7 tons per hectare).

Yield ceilings may be raised primarily through continued emphasis on plant breeding, more intensive management of soils, and development of nutrient- and pest-management systems that are tailored to a region's specific conditions.

Biotechnology will increase yield ceilings, for instance, by allowing breeders to produce plants that are resistant to droughts, frost, salinity, pests, and herbicides. Livestock management can be made more efficient through biotechnology by increasing reproductive rates, reducing losses from diseases, and increasing the weight of livestock for a given amount of feed.[24]

Biotechnology can also be used to develop plants and animals bred specifically for favored characteristics. For example, breeders might create plants that produce more oil or starch and meats that contain less fat. Moreover, by conferring on fruits and vegetables the ability to ripen days or even weeks after harvest—as in the biologically engineered Flavr Savr tomato—biotechnology can help reduce postharvest waste, which is currently estimated at between 45 and 50 percent of global caloric consumption.[25]

Protecting Biodiversity

Despite the nay-saying of neo-Malthusians, the United States will likely be able to easily meet its domestic food needs in 2050. Moreover, the world also has the potential for feeding its 2050 population better than it feeds its current population.

To that end, several plausible scenarios have been constructed that would increase global food supplies between 1993 and 2050 by 2.2 times thus meeting the estimated demand at that time.[26]

One scenario would involve more than doubling total cropland, from 3.6 billion acres (1.4 billion hectares) to nearly 7.9 billion acres (3.2 billion hectares). This is theoretically possible, given that there are at least 8.2 billion acres (3.3 billion hectares) of potential cropland on the Earth's surface. This scenario assumes that farmers would maintain current average yields on both old and new cropland.

Alternatively, to avoid the tremendous loss of habitat and biodiversity implicit in this scenario, yields could be increased by use of existing, as well as new, technologies tailored for local growing conditions around the world.

Consider, for instance, that if average yields increase 1 percent per year, only 865 million acres (350 million hectares) of additional cropland would be needed to meet food demands in 2050. Such a rate of increase, which is below the average rate of improvement in the world's performance over the past 35 years, is realistic in light of the gaps between actual average yields, current yield ceilings, and maximum theoretical yields.

However, these scenarios assume:

- There will be sufficient capital to provide inputs and support the technologies needed to maintain or increase yields and to bring new cropland into production.
- Research and development will continue to bring some new technologies on line and find ways to adapt technologies—both existing and new—to local growing conditions around the world.
- Infrastructure and global trade will expand to ensure that food surpluses as well as supplies and inputs can be transported to where they are needed most.
- Citizens, environmentalists, and policymakers will make the trade-offs necessary to feed the world's billions adequately, if not handsomely.
- The agricultural sector will bolster its ability to compete for land and water. For instance, agricultural interests will be well served if farmers are permitted to establish property rights to water and land.
- Regardless of whether food supplies increase and prices decline, some mechanisms will remain in place to ensure that the poorest among us have access to the nutrition they need.

These scenarios assume that societies will maintain and, where necessary, develop and strengthen the institutions and policies needed to increase economic growth, technological change, and trade. This is particularly important for the poorer developing countries that face the greatest challenges to food security.

Despite soaring populations, the food situation around the world has improved markedly this century, thanks to the combined forces of technology, economic growth, and trade. Today famine and malnourishment remain in decline, and people are generally fed better and more cheaply.

Meanwhile, since the early 1900s, technological progress has saved at least 3 billion acres (1.2 billion hectares) from conversion to cropland worldwide and nearly 1 billion acres (400 million hectares) in the United States alone.

With its ample wealth and land and water resources, the United States should be able to meet its future food needs with few problems, even if its population doubles. However, future global food security is more problematic, and poorer nations are the most vulnerable.

Alternative Futures

Nevertheless, we should see continued progress in the food situation well into the next century and possibly beyond. This improvement will occur, however, only if nations, particularly those most vulnerable, take the steps to bolster economic growth, technological change, and trade. Today, these influences keep the Malthusian specter of hunger and malnutrition in check.

In fact, these forces will also enable more food to be produced per acre of cultivated land as well as help reduce population growth rates, which could eventually lead to population stabilization. Thus the stronger these forces, the more space we can afford the rest of nature.

If, on the other hand, these forces are not strengthened—and history teaches us that neither economic growth nor technological progress is inevitable—Malthus may well be vindicated, at least in the poorer nations.

Forty years ago, the brilliant physicist and mathematician John von Neumann asked, "Can we survive technology?"[27] The question should rather be: Can we—and the rest of nature—survive without it? With technology, we may even thrive. Without it, with human survival at stake, the rest of nature will inevitably become the first casualty.■

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NOTES

1. The views expressed in this essay are the author's and not necessarily those of the U.S. government.

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