PART SIX
Threats to Ecosystems

Issue 18

GLOBAL GRAIN PRODUCTION: *CAN WE BEEF IT UP?*

KEY QUESTIONS

- How did humans domesticate wild grains?
- What are global trends in grain production?
- What are the principal uses of grain in the United States and the world?
- Can global food supplies feed a growing population?

WHY WE EAT

Reduced to its basic chemical components, the human body is carbon, hydrogen, oxygen, nitrogen, and a few other elements. These combine to form more complex, highly organized structures called molecules, such as proteins, lipids, carbohydrates, and nucleic acids. These molecules interact to build even larger and more complex structures: cells, tissues, organs, organ systems, and, ultimately, the unique individual.

Such a system of highly organized, integrated parts, however, does not exist without cost. It is subject to the same laws of physics that affect any matter. Among these is the *second law of thermodynamics,* which states that disorder (entropy) in the universe is increasing and that whenever energy is converted from one form to another, some of the input energy is lost in the process of conversion, resulting in less output energy. Practically speaking, in the natural state, complex, organized systems tend to become simple and unorganized unless energy (in our case, food) is added to the system to keep it organized and complex. Inadequate nutrition leads to undernourishment or malnutrition. Globally, perhaps 1 billion people are malnourished.

Table 18-1 compares foods and feed grains for China, the U.S., and the world.

Question 18-1: Contrast the American diet with the typical Chinese diet.

TABLE 18-1 ■ Selected Foods Available to U.S. and Chinese Consumers (kg per capita per year.)

Food	U.S.	China	World
Food Grain	92	387	158
Vegetables	191	198	167
Fruits	135	35	60
Fiber	12	33	—*
Meat, Fish	91	62	56
Dairy	272	7	79
Fats, Oils	31	5	13
Sugars	72	7	25
Nuts	9	—	1
Animal Protein	11	.8	—**
Total Food	908	715	567
Animal Feed	816	70	150

**Percent of total calories; *grams per day. Sources: Pimentel, David, and Marsha Pimentel, 2003, *Am J Clin Nutr* 2003;78(Suppl):660S–3S, and Campbell, C., and T. Campbell, *The China Study*. Benbella Books, Dallas, TX 2006.

WHAT WE EAT: GRAINS AND THE ORIGIN OF AGRICULTURE

Even though humans are omnivorous and eat a variety of foods, we are extremely dependent on only a few crops: corn (maize), wheat, rice, barley, and soy. Why do we depend so heavily on these relatively few plant species? For one thing, these plants have significant protein and carbohydrates. For another, most wild plants that we could possibly domesticate are useless to us as food—they may be indigestible, very low in food value, or hard to prepare. In fact, most wild biomass is wood or leaves, which we can't digest.

Plant domestication has been defined as "growing a plant, and thereby consciously or unconsciously causing it to change genetically from its wild ancestor in ways that make it more useful to humans."[1] The history of plant domestication is a fascinating one. Here's how domestication may have come about.[2]

Studies of plant remains at human habitation sites tell us when humans first domesticated plants, since domesticated grains are much different from their wild ancestors. Grain domestication was preceded by a major climate warming, resulting from the last glacial withdrawal around 11,000 years ago. This warming led to an expansion of the habitat for the wild grains that were ultimately to be domesticated, making it easier for humans to collect them.

According to carbon-14 dating, grain production probably arose first in the Fertile Crescent of the Near East, where the domestication of wheat from wild varieties occurred by 8500 BCE. It quickly spread along the great east-west axis of Eurasia. The domestication of rice began in China sometime around 7500 BCE. In the New World, corn (maize) was first domesticated by 3500 BCE.

When humans began to grow crops from wild varieties, they would naturally select the varieties that would best suit their needs. Recall that there is a wide variation in appearance of wild fruits like blueberries, blackberries, and strawberries. Generally, early farmers probably selected according to size—the bigger the fruit, the bigger the offspring, or so they may have thought. Cultivated peas, for example, are ten times bigger than their wild

[1] Diamond, Jared. 1997. *Guns, Germs and Steel* (New York: W.W. Norton), p. 114.
[2] Ibid.

ancestors, which hunter-gatherers must have been collecting for centuries. To take another example, the oldest corncob from MesoAmerica was 1 to 2 centimeters long. By 1500, farmers were growing 15-centimeter varieties, and modern cobs may exceed 30 centimeters. Domestication of the plants we take for granted was a process that likely developed over centuries. In fact, it is still occurring. Strawberries were not domesticated until the Middle Ages, and pecans were not domesticated until the middle of the nineteenth century.

Some of the ancestors of the plants we cultivate—eggplant, potatoes, and almonds, for example—were poisonous. These plants do have a *recessive* gene, however, that will not grow poisonous offspring. In the wild, such a gene is likely to stay recessive since animals will likely gobble up any edible varieties. But humans, after a bit of admittedly risky trial and error, would eventually select plants with the recessive gene and begin to grow only forms that displayed the nonpoisonous characteristics they needed. Recessive genes have been of great value to human society. Wild wheat plants have a dominant gene that causes the stalk to disintegrate when the plant's seeds are ripe. This allows the seeds to be spilled upon the ground, permitting them to germinate. But a recessive variety exists that lacks this gene. These stalks don't disintegrate, and this is the wheat plant that early farmers selected.

In short, here is why we became dependent on so few grains:

- Their ancestors were edible and plentiful in the wild.
- They grew quickly and were easily collected and stored.
- They contained protein and were rich in carbohydrates.

Thus, as a result of millennia of trial and error, by the days of the Roman Empire almost all modern grains were being cultivated in some form somewhere.

THINKING CRITICALLY ABOUT GLOBAL GRAIN PRODUCTION

Over most of human history, farmers have increased agricultural output mainly by plowing up forests and natural grasslands. Limits of geographic expansion were reached long ago in densely populated parts of India, China, Java, Egypt, and Western Europe. *Intensification* of production—obtaining more output from a given area of agricultural land—has thus become a "growing" necessity. Particularly in Asia, this has been achieved through producing several crops each year in irrigated "agro-ecosystems" using new, fast-growing crop varieties—the so-called "Green Revolution."

However, growth rates in grain yields have slowed in both developed and developing countries. And future increases in food production may become more difficult because environmental and social factors must now be taken into account as we develop new crop technologies. An illustration of the latter is the growing controversy over genetically modified foods, which we briefly discuss in Issue 28.

Let's start our analysis by considering the following quotation from Bailey, 1995.

> Food is more abundant and cheaper today than at any other time before in history. Per capita grain supplies have increased 24 percent since 1950, while food prices have plummeted by 57 percent since 1980.
>
> Food production has outpaced population growth since the 1960s. The increase in food production in poor countries has been more than double the population growth rate in recent years.[3]

Now, consider this quotation from Lester Brown of Earth Policy Institute.

> The 2006 world grain harvest is projected to fall short of consumption by 61 million metric tons (mmt), marking the sixth time in the last seven years that production has failed to satisfy demand. As a result of these shortfalls, world carryover stocks at the end of this crop year are

[3] Bailey, R. (ed.) 1995. *True State of the Planet* (New York: Free Press), p. 50.

projected to drop to 57 days of consumption [or 319 mmt], the shortest buffer since the 56-day (low) in 1972 that triggered a doubling of grain prices.

World carryover stocks of grain, the amount in the bin when the next harvest begins, are the most basic measure of food security. Whenever stocks drop below 60 days of consumption, prices begin to rise.[4]

Janet Larsen of the Earth Policy Institute had this to say about the 2011 harvest:[5] "The U.S. Department of Agriculture [reports] a global grain harvest of 2,295 million tons, up 53 million tons from the previous record in 2009. Consumption grew by 90 million tons over the same period to 2,280 million tons. Yet with global grain production actually falling short of consumption in 7 of the past 12 years, stocks remain worryingly low, leaving the world vulnerable to food price shocks."

Brown further notes, ". . . world grain demand, traditionally driven by population growth and rising incomes, is also now being driven by the fast-growing demand for grain-based ethanol for cars."[6]

Question 18-2: Are the Bailey and Brown statements consistent with each other? What additional information would you need in order to choose which statement(s) is/are accurate?

Figure 18-1 shows world grain production from 1960–2011.

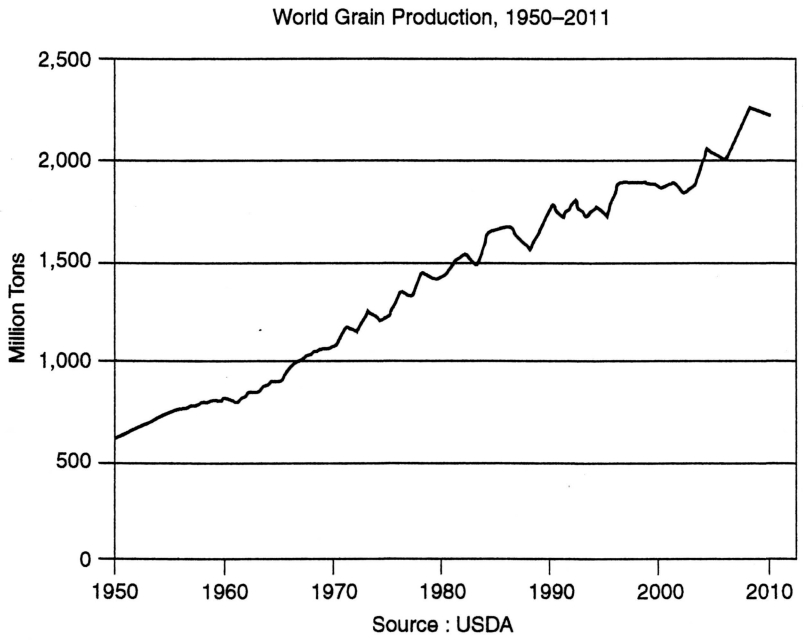

FIGURE 18-1 World grain production from 1950–2011 (USDA).

[4] Earth Policy Institute, www.earth-policy.org/indicators/C54/grain_harvest_2006.
[5] Earth Policy Institute, http://www.earth-policy.org/indicators/C54/grain_2012.
[6] Earth Policy Inst, op cit.

Question 18-3: Describe the change in global grain production between 1960 and 2011.

Question 18-4: In 1960 world population was 3.03 billion. In 2011, world population was 6.9 billion. What was per capita grain production in 1960 and 2011?

Question 18-5: Research the production of ethanol. How do you think ethanol production for a transport fuel will affect grain supplies? What evidence would you need to fully answer this question?

We briefly consider the impacts of producing ethanol from corn in "For Further Thought" at the end of this Issue.

GRAINLAND AREA

In the United States, many rural and suburban dwellers are used to seeing farms being converted into residential subdivisions with miles and miles of tract homes serviced by highways and power lines. (The "Poster Child" for this effect may well be California's Central Valley.) At the same time, there has been intensification of agricultural land use around some major foreign cities (and even within cities), particularly for high-value perishables such as dairy and vegetables but also to meet subsistence needs. Globally, grain area harvested per capita has fallen from 0.21 ha in 1960 to 0.1 ha in 2010.[7]

Figure 18-2 shows global grain price changes since 2005.

Question 18-6: Refer to Figure 18-2 and the quotations from Bailey and Brown on page 177–178. Which one does your assessment tend to support? Explain your reasoning.

Although the per capita grainland harvested has decreased by 50 percent from 1960 to 2012, this decrease has been offset by compensatory increases in output per hectare achieved by high-yield farming. Called the Green Revolution, the development and use of new strains of wheat and rice along with greater irrigation (Figure 18-3), input of fertilizers, pesticides, herbicides, fungicides, and so forth, drastically increased crop yields.

[7] www.worldwatch.org/node/554.

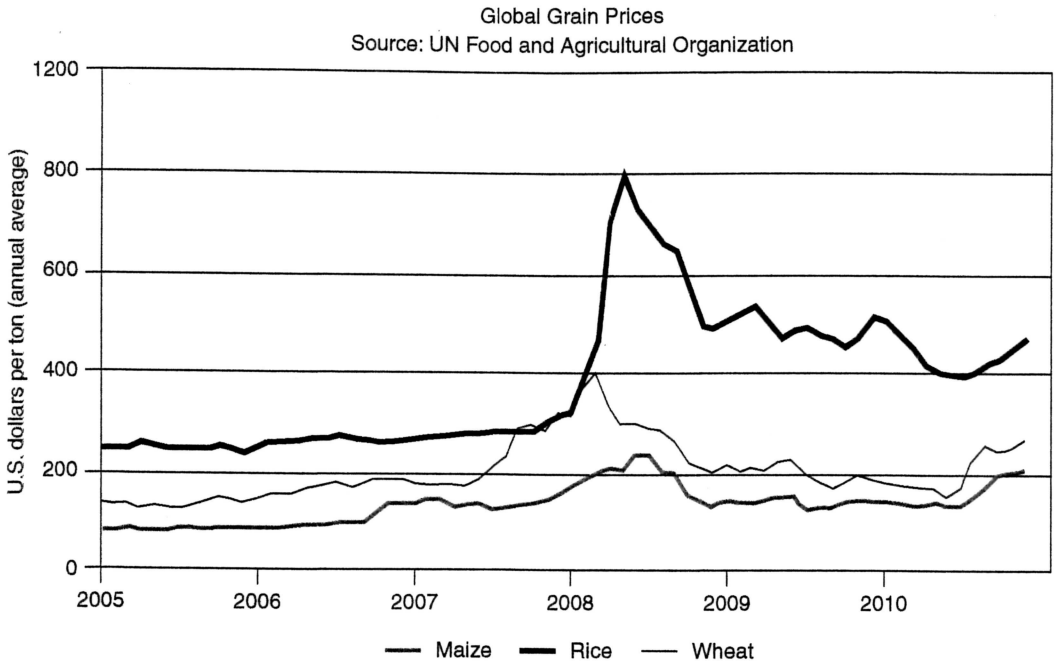

FIGURE 18-2 Changes in global grain prices since 2005 (UN FAO).

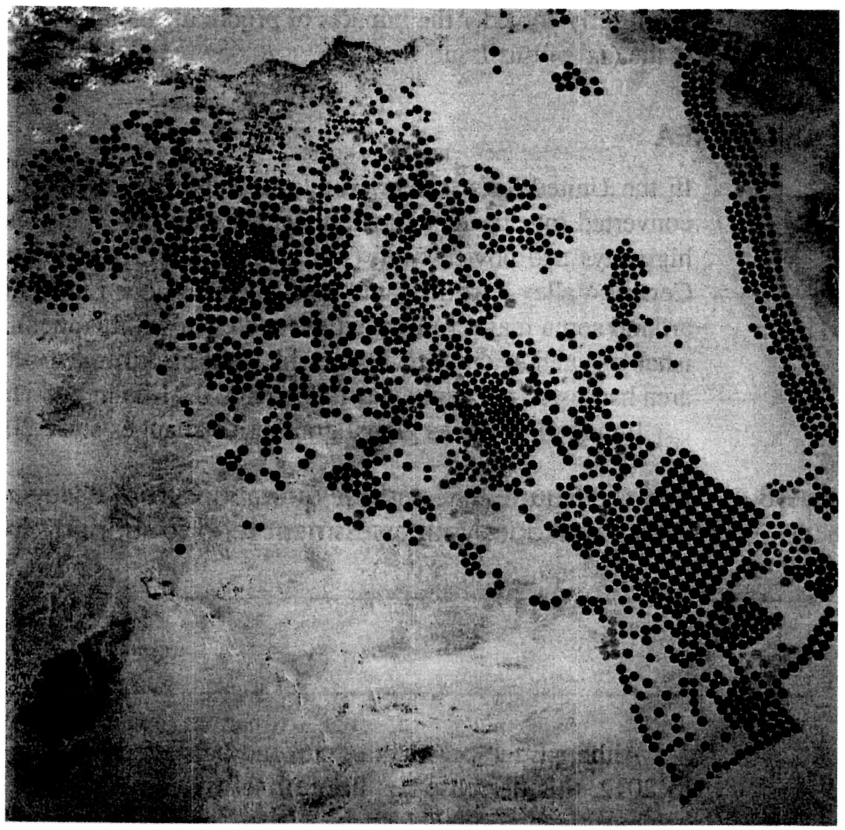

FIGURE 18-3 High altitude space photo of irrigated fields in the Arabian desert. Irrigation water is from 1,300 m deep aquifers. Circles are approximately 0.5 miles (550 m) in diameter (Courtesy of Corbis Images.).

GRAIN AND MEAT PRODUCTION

World meat production was 296 million tonnes (mt) in 2011. It was 44 mt in 1950.

Question 18-7: Calculate the per-capita meat production for 1950 and for 2011, then characterize the change in global per capita meat production between 1950 and 2011. Global population was 2.56 billion in 1950, and 6.98 billion in 2011.[8]

Economic growth in Asia has helped fuel this increase. Annual per capita meat consumption ranges from about 124 kilograms in the United States to 75 kg for Greece, 53.4 kg in China to around 3.2 kilograms in India. Some 15 billion livestock (11 billion of which are poultry) exist at any one time to satisfy this demand[9] (see Figure 18-4).

Question 18-8: Does an increase in meat consumption signal improving global nutrition? Explain your answer.

Much of the world's grain harvest is fed to cattle and other livestock. In 1960, 294 out of 822 million tons of grain were used as animal feed. In 2006, the Earth Policy Institute estimated that 714 mt (million tons) out of a total global grain harvest of 1,984 mt were fed

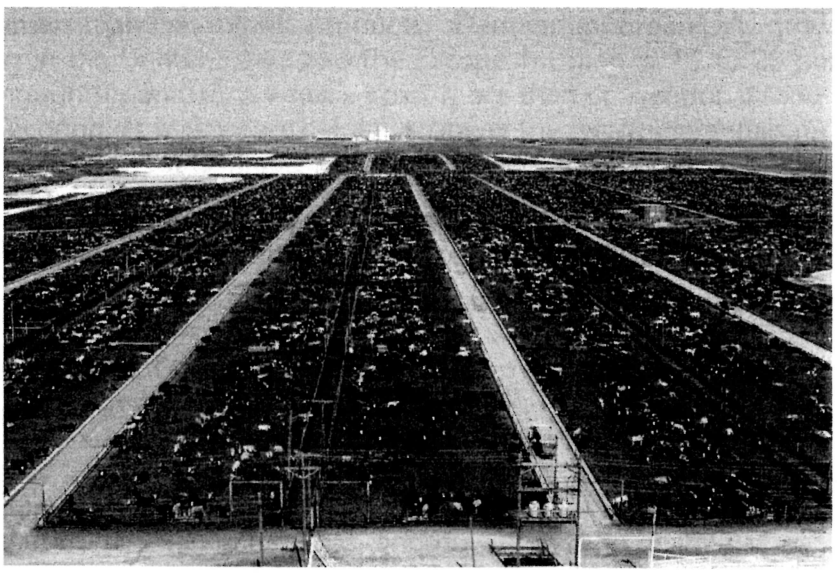

FIGURE 18-4 Cattle feedlots near Lubbock, TX. (Courtesy of Richard Hamilton Smith/Corbis Images.)

[8] U.S. Dept. of Agriculture, www.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf.
[9] For details see http://chartsbin.com/view/bhy.

to animals. China News reports that as of 2011 70% of Chinese corn (maize) production was used as feed.[10]

Question 18-9: About what percentage of the global grain harvest was fed to animals in 2006?

According to the U.S. Department of Agriculture, nearly 25% of corn grown in 2011 was used to produce ethanol. High-protein "corn cakes" a byproduct of ethanol production, is now a major agricultural export. Additionally, about 60% of all grains produced during the late 2000s was used as animal feed.

Pimentel and Pimentel estimate that a switch to grass-fed livestock in the United States would allow about 130 million tons of grain to be diverted to human consumption, which could feed about 400 million people annually.[11]

Question 18-10: Should we discourage meat consumption or ethanol production, or encourage grass feed instead of grain for livestock to free grain to feed the world's hungry? Explain your answer.

Question 18-11: Prime farmland is disappearing around large U.S. cities. The land is being used for housing, roads, office buildings, and shopping centers. Some have questioned whether it is "economical" to convert farmland around cities into enormous parking lots for grocery stores in which food grown thousands of miles away is sold. Do you concur? Discuss and defend your answer using critical thinking principles.

Question 18-12: Under what conditions will it be possible to feed a global human population of 9+ billion? Speculate on what the planet's environment would be like in such an eventuality.

Question 18-13: Discuss Issue 18 from the perspective of sustainability and sustainable societies.

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[10] www.xinhuanet.com/english/.

[11] www.news.cornell.edu/releases/Aug01/corn-basedethanol.hrs.html and Pimentel, D., & M. Pimentel. 1996. *Food, Energy, and Society* (Niwat, CO: University Press of Colorado).