Chapter 11

PRODUCING ENOUGH FOOD FOR THE WORLD: HOW AGRICULTURE DEPENDS ON ENVIRONMENT

Case Study: Biofuels and Pigs

- Today, there is competition between the new biofuel industry and the food industry for edible crops. Diversion of corn from food production for humans and commercial livestock, such as pork and chickens, has caused farmers to seek alternative foods, such as trail mix, for the animals instead of corn and wheat. This use of traditional food products to produce biofuels will have negative effects on the efforts of many developing countries to feed their growing populations.

11.1 CAN WE FEED THE WORLD?

● Agricultural land now accounts for 11% of the earth's land area. This is huge. See Table 11.1. Crop land in Europe accounts for 22% of land area. Thus, a large fraction of the earth's NPP is being diverted away from natural ecosystems and food webs and is being used to support people.
● As human population increases, the amount of land under cultivation must increase, or yields must increase, or both, and the impact on the environment will increase.
●An important point about the distribution of food production is that it does not correlate with the density of people. As natural populations approach their carrying capacity, we often see limitations imposed by food supply. The evidence for this in human populations is poor, considering the global patterns, because food can be transported.
● The world currently produces enough food to support its population, but there are areas where mass starvation occurs, because the importation of food is not based on need. Food supply is based on ability to pay.
● The pattern of global food production depends on climate, soil, wealth, infrastructure, and geopolitical factors (e.g. war).
● Future increases in production will depend on increasing yield and less so on increasing the amount of land under cultivation. In fact, since 1950, gains in agricultural production have resulted mainly because yields have increased (the green revolution); all of the highly productive land is already under cultivation.
● North America is by far the greatest exporter of food worldwide, with Australia/New Zealand a distant 2nd. Africa and Asia are large importers. See a Closer Look 11.3 for a discussion of measures of food availability and estimates of the supply situation.

11.2 NUTRITIONAL DISEASES

● The two most common nutritional problems are marasmus and kwashiorkor , which are due to deficiencies of calories and protein, respectively. The WHO has defined hunger and starvation on the basis of the number of calories consumed relative to the Basal Metabolic Rate (BMR). The BMR is the number of calories required to sustain human life while in the resting state. Undernourishment is defined as 1.2xBMR

● Famine is a common occurrence, and ironically food aid can exacerbate the problem by competing with local growers.
● There are other nutritional diseases such as goiter, caused by iodine deficiency, anemia- caused by iron deficiency, and blindness- caused by vitamin A deficiency.
● Infant formula is heavily marketed in 3rd world nations, and this is a leading cause of malnutrition in infants as families discover they cannot afford the cost of the formula.

11.3 WHAT WE EAT AND WHAT WE GROW

●Only about 150 plants have been used as crops on a large scale, and only 14 of these are significant in terms of total food energy. The 3 most important cereal crops are wheat, corn, and rice.
● The animal protein that we consume consists of 14 billion chickens annually, 1.3 billion cattle, >1 billion sheep and ducks, about 1 billion pigs, and others. See Fig. 11.10 The amount of land required to support a human increases as the amount of animal protein in the diet increases.
● Aquaculture: farming of fin or shellfish in ponds. Products include shrimp, crawfish, catfish, salmon, and others. These are highly intensive operations that can have a large environmental impact. Food is imported to feed the animals creating water quality problems. In some areas, like Ecuador, large areas of mangrove forests (which supported an important coastal fishery) have been bulldozed and replaced by shrimp ponds. Much of the shrimp crop now consumed in the U.S. is from Ecuador.
● Mariculture: farming of fin and shellfish in the ocean. This can be in pins or floating racks. Products include oysters and mussels.

11.4 AN ECOLOGICAL PERSPECTIVE

● Agricultural environments are evolutionarily unique environments. They are ecosystems of very low biodiversity (usually monocultures) that are maintained in a state of early ecological succession. Crop plants were domesticated largely from early succession species.
● Unlike natural ecosystems that are spatially complex environments, agiecosystems are spatially simple, which increases the chances for pests and diseases to spread.
● Food chains in agiecosystems are as simple as we can make them. The use of pesticides is huge and has a global environmental impact.
● The soil is usually highly disturbed, which increases the loss of organic matter and nutrients, and increases erosion. Nutrients, especially N and P, are added to the soil in ever increasing amounts to replenish the soil and to increase yield.
● Crops have an unusually low degree of genetic variability and, increasingly, transgenic crops are being used. Low genetic variability also increases the chances for crop disease and vulnerability to pests.
● Irrigation: the competition for water is a growing concern in many areas. In California for example there is fierce competition for water that requires the almost total diversion of water from natural ecosystems.

11.5 LIMITING FACTORS

● Liebig's Law: the growth of a plant is limited by one factor at a time – the one whose availability is smallest in relation to the requirement. For example, if a plant needs 4 g of

N and 1 g of P to produce 100 g of tissue, and 2 and 1 g of N and P are available, respectively, then only 50 g of tissue can be produced. Production can be increased only by adding more N. Liebig's Law pertains to nutrients. It is common that resources like water can be co-limiting. In fact, CO_2 is a limiting factor for photosynthesis and is an important issue related to global climate change.

● In agricultural as well as terrestrial ecosystems, usually N is the first limiting nutrient followed by P. In some situations there are limitations by one or more micronutrients, particularly after providing N and P.

A CLOSER LOOK 11.1 Traditional Farming Methods

● In less industrialized, tropical areas, there is a history of agricultural methods that depend on clearing the vegetation without plowing. Where the loss of nutrients from the soil occurs rapidly following clearing, as in some tropical rain forests, the traditional practice is to cut the forest in small patches but not cut it completely (Figure 11.13).cation exchange capacity is good as it helps soil to hold the nutrients. For many years, agricultural experts from developed nations viewed this method of agriculture as a poor process with low, short-term productivity, used only by primitive peoples. Now it is understood that this kind of agriculture is well suited to high-rainfall lands where soils readily become impoverished when the land is completely cleared.

11.6 THE FUTURE OF AGRICULTURE

● Approaches: 1) mechanized, industrial scale agriculture puts a premium on maximizing yield, and profit; 2) resource-based, in which resource conservation and sustainability are important. Biotechnology and other forms of high tech are important tools. 3) Organic-like #2, but there is a premium placed on the production of foods without the use of chemical fertilizers and pesticides. Approaches 2 and 3 are usually more labor intensive and produce lower yields, but organically grown produce commands higher prices. See a Closer Look 11.1 for a discussion of traditional farming practices.

● Biotechnology will play an increasingly greater role in agriculture. Possibilities include the production of diseases bioengineered to attach pests, genetic varieties of plants that do not require nitrogen fertilizer, crops that are resistant to pests and disease, and crops that overproduce biochemicals that are important to human health. See a Closer Look 11.2

● As biologists document new species, there is a possibility for domestication of new crop species, or of the engineering of existing crop species using genes taken from other plants. For example, imagine how a perennial species of corn, *Zea perennis*, discovered in Mexico, could transform agriculture.

11.7 INCREASING THE YIELD

● Since 1950, gains in agricultural production have resulted mainly because yields have increased (the green revolution). This is energetically expensive. Industrial nations use about 10 cal of fossil fuel energy to produce 1 cal of food energy. Most of this energy is used to produce the chemicals that we use in agriculture. We have increased yields by

applying chemicals (pesticides and nutrients), water, and by selectively breeding crop plants. Agriculture in the U.S and Canada will not be limited by land, but it will be limited by fossil fuel and water.

11.8 ORGANIC FARMING

● The impact of agriculture on the environment can be minimized by adopting a style that is close to what is commonly referred to as organic farming. Organic foods are not chemically adulterated with pesticides or hormones, and may be safer for human health. Environmental impacts are minimized by organic farming, and organic techniques are by design meant to be sustainable.

A CLOSER LOOK 11.2 Potential Future Advances in Agriculture

● New genetic strains and hybrids by genetic engineering can improve human nutrition and reduce the use of fertilizers and pesticides.
● New crops can be developed.

11.9 ALTERNATIVES TO MONOCULTURE

● Modern industrial agribusiness maximize yield by raising monocultures of genetically uniform plants that are tailored to the soil and climate, but that are vulnerable to pests and disease in the absence of massive use of pesticides.
● Mixed cropping systems can reduce the risks of major pest and disease problems. Mixed cropping systems are an important tool used by organic farmers.

11.10 EATING LOWER ON THE FOOD CHAIN

● Some people advocate eating lower in the food chain as a means of minimizing the ecological footprint. This is a worthy cause, but can lead to heath problems if carried to an extreme. It is difficult to obtain all of the essential amino acids from a strictly vegetarian diet. Our biochemistry is the product of our evolution as omnivores. That said, we can reduce meat consumption, and we can consume animal protein that is energetically and ecologically efficient.

11.11 GENETICALLY MODIFIED FOOD

● Are public fears and distrust of ‘genetic engineering’ based on ignorance or knowledge?
● Genetic engineering is not fundamentally different from what has happened naturally during the course of evolution, or deliberately by people who have practiced selective breeding. It is just faster. The fact is that genes cross species boundaries all the time. They are carried by viruses. The human genome is loaded with bacterial genes introduced by viruses, some useful, most probably just useless junk. Natural selection is a powerful force that acts quickly to eliminate poorly adapted organisms. The chance that humans will accidentally produce a monster organism that will wreak havoc is vanishingly small, because the odds are small that an engineered organism will be better adapted than a natural organism that has been optimized for its environment by thousands or millions of years of natural selection.

● On the other hand, there are risks, such as the risk of introducing a novel biochemical into the human food chain that could elicit an allergic reaction or possibly even cancer. See critical thinking issue below.

11.12 CLIMATE CHANGE AND AGRICULTURE

● Global climate change may greatly alter the distribution of global food production primarily because of changes in the distribution of rainfall. The prospects for agriculture will improve in some areas and decline in other. North America, which is currently the bread basket for the world, could loose this advantage. This has geopolitical implications.

● Another aspect of global climate change is the rising concentration of CO_2 in the atmosphere. This is a factor that, all else being equal, will raise the rate of photosynthesis and hence the productivity of many crop plants (C3 plants), but not others (C4 plants).

CRITICAL THINKING ISSUES

● Genetic Engineering

In the fall of 2000, genetically modified corn that had not been approved for human consumption was found in taco shells in the United States. The corn, produced by Aventis for animal feed, was found in a range of foods, prompting product and grain recalls countrywide. A panel of experts assembled at the request of the EPA concluded that the probability of harm to people was "low". The cause for alarm was a bacterial protein known as Cry9C, the gene for which was added to StarLink corn to make it resistant to insects. Cry9C is more heat stable and harder for humans to digest than its kin--qualities that are typical of such allergens as peanuts, and the fear was that the novel protein could cause severe, even fatal, allergic reactions in people. Comparisons of Cry9c's structure with known food allergens turned up no signs of allergenicity, but EPA's scientific advisers did not consider those tests conclusive. In 1998 Aventis applied to have StarLink corn registered for human consumption, but the EPA limited its sale to animal feed and industrial uses. What happened was that there was little information for farmers about how to keep this corn sufficiently isolated from other varieties, and no oversight. Corn is wind pollinated. If the transgenic variety is planted next to a crop destined for direct human consumption, there can be movement of genes back and forth between the populations. See Science, Vol 290, Issue 5498, p.1867, 8 December 2000. What should be done to safeguard the human food chain from potentially harmful bioengineered products? Should biotech companies be liable for mistakes made by people in the food supply chain?

● Water Supply Issues

Increasingly there is competition for water between urban areas and agriculture. Agriculture is responsible for consuming more water than any other human endeavor. Water supply in the far west is crucially short and the fertile The San Joaquin Valley in the heart of California is the state's top agricultural producing region. Sometimes called "the nation's salad bowl" for the great array of fruits and vegetables grown in its fertile soil, the San Joaquin is a national resource. This productivity is threatened by water demand by the growing populations of LA, San Diego, Phoenix, and Tucson. Another area of concern is the mid-west in the heart of the grain belt where ground water from the

Ogallala. In about five percent of the aquifer, water levels have already declined below 30 feet. Wells were being installed at a rate of approximately 80 per year in the 1950s. Thirty feet is considered the minimum amount necessary to support large-scale irrigation. Policies developed in response to depletion of the aquifer must be technically, economically feasible, and politically and socially acceptable. For example, the suggested large-scale interbasin water transfers to this region from the Great Lakes or some other river basin may be sound technical projects but they face considerable social and political opposition. These are clearly national resources. Should they be regulated? At what level – local, state, or federal? Should land owners be compensated if they are denied the free use of a water resource on or below their property?

Web Resources

www.fao.org/ag This site has a wealth of information on fertilizer use, genetics, irrigation, soil, fisheries and other subjects related to food production and the global food supply. There are also links to other sites.

http://www.nass.usda.gov/index.asp This is probably the best source of statistics on food production in the U.S. You can also find detailed data on pesticide use by name, by crop, by state, and year.

http://earthtrends.wri.org/datatables/index.php?theme=8 A site with useful statistics on global crop production.

http://www.geo-pie.cornell.edu/crops/corn.html A site devoted to the genetic engineering of foods.