Chapter 1

Agricultural Trends and Realities

I was born on a small farm in Northwest Missouri half a century ago. By 1956 most farms in the area had electricity and were connected by gravel roads to the main highways. Most farms had hedges that provided posts for fences and cover for wildlife. Farm families produced much if not most of their own food, fresh in the summer and canned or stored in root cellars during the winter. Most farms had a milk cow and hens for eggs. In the summer most raised chickens and had vegetable gardens for fresh food. Fruit trees and even beehives were common as well. Virtually every farm had ponds to reduce runoff and erosion, provide water for livestock, and provide fish (and waterfowl in season) for food. Many had woodlots that supplied firewood to heat the homes.

Farming in the 1950s consisted of growing a mix of crops in rotation with corn as the staple. These included wheat, soybeans, and oats. Clover was often planted to provide hay after the wheat or oat harvest and to build the soil. Midwestern farms also had pasture and produced hay for beef cows that were relegated to more rugged land in the summer and allowed to graze on the crop fields after harvest. Corn-fed pigs provided an easy way to get more cash from the corn crop. Farming was mechanized. Tractors had replaced horses to pull plows, discs, harrows, planters, cultivators, and harvesters through the fields. Cultivators were used to till the soil and kill weeds as the crops grew. In some instances, row crops like corn and soybeans were cultivated two to three years in a row. Weed killers were used on corn, but usually only on a spot basis and only if weed infestation was particularly heavy; otherwise, farm children normally walked the rows to cut weeds. The average row crop was produced with six to seven passes of a tractor pulling different equipment over the course of three to five months.

By the 1960s different U.S. government programs encouraged farmers to increase their farm and field size as well as the intensity of crop production. Fewer, more valuable crops were produced. Not only did farm size increase, so did land value, fixed investments in machinery, and the overall use and cost of inputs such as fertilizer and pesticides. Fencerows, waterways, and the last vestiges of blue stem prairie were eliminated in the quest for greater efficiency. Many pasture areas that were considered too poor quality to farm in the past went under the plow. Erosion increased. Wildlife, once common on farms, was virtually eliminated. Ponds and streams became loaded with sediment, nutrients, and pesticides. For the first time, farm families became dependent on purchased food. Well water was no longer safe to drink on most farms. The average crop was produced with about the same number of passes of a tractor, but the activities were different. While more efficient soil preparation meant fewer passes, additional tractor passes were needed for fertilizer and pesticide applications.

As farming changed, communities changed. Farmers have always depended on inputs and services from others. Prior to World War II, small crossroad commercial centers existed about every five to eight kilometers (three to five miles) around the countryside.

They usually consisted of a blacksmith shop, feed store, general store, and a church. By the 1950s communities flourished at intervals of about 17 kilometers (ten miles). These communities consisted of blacksmith shops, feed stores, schools and churches, grocery stores, and clothing and hardware stores. By the 1970s most commerce was shifting to larger towns spaced about every fifty to eighty kilometers (thirty to fifty miles). And farmers became as aware of weather patterns in Europe, Argentina, and Brazil as they were of those in neighboring states.

Similar trends have occurred in other parts of the world. More efficient production has led to lower prices. As prices dropped, market-oriented producers have attempted to increase their income by increasing their holding size as well as the intensity of production. Many smaller producers who found themselves unable to compete with the volume of large-scale producers have identified new crops, found ways to add value to traditional crops, or simply become marginal subsistence farmers. In 2000, for the first time, the number of small farmers in the world declined, implying that many small producers could no longer support their families by producing their own food, or perhaps that life elsewhere was preferable to the marginal, isolated existence of farming.

While the specifics and the speed of the changes have varied around the world, agriculture and its relationship to societies has changed everywhere. Governments have become much more involved not only in agricultural production but also in seed and agrochemical development, product development and promotion, and currency and trade issues. Globally, increased urbanization, the expansion of markets, and increased trade in raw materials as well as manufactured products have stimulated technological changes and increased overall scales of production. At the same time, increasing awareness of global food production systems has made consumers more concerned about the quality of food they eat as well as how it is produced. These same factors have made the food industry ripe for both vertical integration (where a company controls ownership of a product for all or most stages, from production to the consumer) and consolidation.

Mechanization, new inputs such as fertilizers, pesticides, and technology, improved crop varieties, and government support and protection have tended to cushion producers around the world from many market realities. Globalization is changing that. In the past producers competed with their neighbors for local markets. As transportation improved, producers competed at regional and even national levels while government protected them from foreign imports. Today most agricultural production is still consumed in the country of origin, but globalization promises to change that, too.

As technology has come to dominate producers' decisions about how to solve problems, responses have tended to focus on a single technology (e.g. seed, fertilizer, pesticides, tillage, or water) or rather simple combination packages of the individual technologies. Subsidies accentuate this response. One consequence is that in the past century, more producers are planting single crops, with fewer rotations. This has resulted in the loss of an estimated 75 percent of global agricultural biodiversity. It is simply too complicated to find ways to improve the production of each of the wide range of plants and animals that have developed in local niches around the globe over millennia.

The overarching goal of agricultural research has been to identify and focus only on those species or varieties promising the most potential for economic gains. India, for example, is rapidly replacing 30,000 varieties of rice with a single variety. By the year 2000, 75 percent of the world's food came from seven crops—wheat, rice, corn, potatoes, barley, cassava, and sorghum. Some 60 percent of the world's food calories came from the first three alone. If soybeans, sweet potatoes, sugarcane and beets, and bananas are added, these crops account for 80 percent of total crop tonnage (Kimbrell 2002). This simplification is shortsighted at best, and fails to take into account the current reality of agricultural production and its future consequences.

The Current Reality

For more than 99 percent of human history, people obtained their food by hunting, fishing, and gathering. Over the past 7,000 years that has changed remarkably. Today only 2 percent of all human food energy and only 7 percent of all protein is captured from the wild, and most of this is from water. The rest is produced by agriculture and aquaculture on land.

As a result, agriculture is the largest industry on the planet. It employs an estimated 1.3 billion people and each year produces some $1.3 trillion worth of goods at the farm gate. In the developed world, food prices (in real terms) have fallen by 40 percent over the same period. For example, because of overall increases in per capita income and relatively cheap food, Americans spend only 14 percent of their income on food. Europeans, on the other hand, spend some 44 percent more on food than the rest of the developed world. In developing countries, however, the poor can spend as much as 75 percent of their total income on food.

Not only has the percentage of income spent on food tended to decline in the United States, but the percentage of those dollars kept by farmers has declined as well. In 1900 an American farmer received some 70 percent of every dollar spent on food. By 1990 U.S. farmers received an estimated 3 to 4 percent of the money spent on food. Globally, agribusiness produced $420 billion in 1950, and farmers received a third of it. Researchers estimate that by 2028, the total global market for agricultural production will be $10 trillion and farmers will receive 10 percent of it.

Part of the reason that less and less money goes to the farmer is that more "value" is added to agricultural products than ever before. In the past farmers sold products in open markets and received a large portion of the consumer price. Today, the consumer's cost of food includes manufacturing, quality control, preservation and packaging, labeling, distribution and handling, storage, advertising, compliance with laws and regulations, professional management, and even the cost of air-conditioned supermarkets. While food prices have steadily declined, the cost to manufacture, hold, distribute, and sell food has increased, further squeezing farmers. American farms represent only 0.9 percent of the country's gross domestic product (GDP), but the food market chain—those who sell to and buy from farmers—is about fourteen times as large. The price of a cup of coffee has

more to do with the convenience and ambience of where you buy it than the cost of the beans. Similarly, the Coca-Cola Company spends more on each can than on what is in it.

As a consequence of increases in productivity and economies of scale, the number of farmers around the world is declining in absolute terms. In the United States farmers represent less than 1 percent of the population, and they not only feed the rest of the population but also produce enough for this country to be the largest exporter in the world. Only 18 percent of U.S. farms produce 87 percent of the food. Farming populations in France and Germany have fallen by half since 1978. In countries belonging to the Organization for Economic Cooperation and Development (OECD), the number of farms is declining by 1.5 percent per year, and farmers and their families now represent only 8 percent of the population. In short, throughout the world there are fewer, more highly productive farms every year.

Past success in increasing food production and lowering costs does not imply that there will be sufficient food in the future. There are several worrying trends. First of all, as discussed later in this chapter, hunger issues are as much about distribution and income as production. Second, production will not keep increasing forever. Global food demand is likely to double over the next fifty years. While total cereal production has doubled in the past forty years, the increase in yield growth rates have declined from 1987 to 2001, indicating that productivity is nearing its genetic and resource limits. The world's population is expected to increase another 50 percent by 2050. Increased affluence (projected as a 2.4-fold increase in per capita real income around the globe by 2050) is leading to increased consumption of meat and animal products, which requires additional agricultural production (Tilman et al. 2002). In the United States it takes 0.42 ha (45,000 square feet) of agricultural land to feed a single person eating a high-animal-protein diet. This model will not work in developing countries where there is only about 0.08 ha (9,000 square feet) of agricultural land per person available for cultivation. Furthermore, per capita land availability is decreasing worldwide.

Problems with Large-Scale Production

Most agricultural systems around the world are evolving into larger, more specialized units of production owned by fewer and fewer people. In Brazil, for example, 80 percent of the land is owned by 10 percent of the population. In the United States 163,000 large farms now account for 61 percent of sales, while only 50,000 farms produce 75 percent of all food.

Efficiency is today's key agricultural issue—production per hectare, production per unit of fixed and/or working capital investment, cost per unit of production, cost per unit of key production input, etc. In general, smaller farms (those less than 11 hectares) are more efficient producers than bigger ones in terms of production per area of land. Studies from around the world show that smaller farms almost always produce more product per unit area than larger ones. The cost of production per unit produced increases with farm size. This is true at least in part because smaller farms are usually run by families, and the cost

of family labor is not included in their calculations of costs. Mid-sized and larger small farms, on the other hand, are more economically efficient when labor and technology are included in the calculation.

A 1992 U.S. agricultural census found that smaller farms are 2 to 10 times more productive than larger ones and 10 times more productive per acre than farms of 6,000 acres or more. The smallest farms (1.6 hectares or less) were 100 times more productive per acre than farms of 2,400 hectares or more. The problem with such small farms is that most of the farmers, unless they have very valuable cash crops, cannot make a living from farming alone and must subsidize their income with off-farm employment.

In addition, market factors often outweigh local economic or environmental efficiencies in the marketplace. Simply put, it is easier to purchase larger amounts from a smaller number of suppliers. Nowhere is this clearer than with livestock. During the past forty years, global per-capita meat consumption has increased by 60 percent. To meet this increased demand, livestock production is increasingly industrialized, with several thousand cattle or pigs or 100,000 chickens often raised in a single facility. Over the past fourteen years, the average size of animal operations in the United States has increased 1.6-fold for cattle, 2.3-fold for pigs, 2.8-fold for eggs, and 2.5-fold for chickens. In Canada pig operations have increased 2.6 times in size in ten years (Tilman et al. 2002).

Such operations come with costs, often in the form of diseases. In 1997 a chicken virus in Hong Kong killed six people and resulted in the slaughter of 1.2 million birds. Outbreaks of foot-and-mouth disease in the United Kingdom resulted in 440,000 animals being put to death in 1967 and 1.2 million in 2001. Bovine spongiform encephalopthy (BSE, more commonly known as mad cow disease) resulted in the slaughter of 11 million animals in 1996 (Tilman et al. 2002).

In North Dakota most "farms" now are greater than 8,000 hectares, but they are not single properties. Most have been pieced together through years of acquisition and often consist of many small farms 50 to 100 miles apart. While spreading out the holdings may reduce localized climatic risks, such farms are less efficient to operate. More importantly, owners cannot afford more environmentally sensitive management practices and cropping patterns. When the land being farmed is spread over such a wide area and the time window for management and cropping is so narrow, it is impossible to monitor the conditions on each plot and move machinery back and forth to deal with small-scale problems. It is simply easier to farm single crops with uniform management interventions. It is clear that the most efficient interventions are made as a result of monitoring and tailoring the response to the observed problem. On such large farms it is difficult to monitor crop conditions and pests for areas that are less than 1 square kilometer. This scale is simply too large for the most effective and efficient management.

These patchwork farms were created not in response to normal market incentives but rather because of government policies. U.S. commodity programs encourage wheat (and corn) producers to acquire more base acres (from which subsidies are calculated) in order to receive higher government payments. As a consequence such farmers may be producing wheat, but what they are really growing is government subsidies.

There are other troublesome issues regarding farm size. As farm size increases, poverty in local communities and absentee ownership increase as well. In addition, as farm size increases in rural areas, crime tends to increase while the number of local businesses decreases (Kimbrell 2002).

Scale issues are not limited to conventional high-input farming. In the United States, at least, organic production is even more concentrated than conventional agriculture. In California, five farms control half of the state's $400 million organic produce market. Horizon Organic in Colorado controls more than 70 percent of the nation's organic milk market. Until recently it produced more than 30 percent of its milk on only two dairy farms (Baker 2002; Pollan 2001). Similarly, in Brazil a tiny fraction of the total number of farms account for almost all of the millions of hectares of no-till agriculture.

Productivity does not depend on size alone. Well-managed farms are always more productive than poorly managed farms of the same size. They use fewer chemicals, fertilizers, and antibiotics per unit of production; they also have lower production costs, fewer and less severe environmental impacts, and fewer health problems than less well-managed farms. Because well-managed farms have equal or higher yields, they are more profitable and environmentally preferable.

Agriculture and Society

Agricultural production reflects the inequities of societies. There are more than 1.2 billion people on the planet who live in absolute poverty, earning less than $1 a day. Twice that many people survive on less than $2 a day. The Food and Agriculture Organization of the United Nations (FAO) estimates that 830 million people in the world are underfed. Almost 80 percent of the world's hungry live in rural areas and depend on agriculture to make their living. While at one time, wild-harvested food fed many of these people, today half a billion rural poor are landless or lack sufficient land to produce what they eat or the income to buy it. From 1970 to 1990 the number of hungry people in every country except China increased by an average of 11 percent (Kimbrell 2002).

Hunger issues are as much about distribution and income as production. There is enough food for everyone on the planet to have 3,500 calories a day. In fact, there is sufficient food to provide everyone on the planet nearly 2 kilograms (4.3 pounds) of food every day, including 1.14 kilograms (2.5 pounds) of grains, beans, and nuts; 0.45 kilograms (1 pound) of fruit and vegetables; and nearly another 0.45 kilograms (1 pound) of meat, milk, cheese, and eggs (Kimbrell 2002). Over the past thirty-five years, per capita food production has grown 16 percent faster than population. Still, people are hungry. There is growing recognition that agriculture has a major part to play in improving this situation (DFID 2002). For example, in Africa agriculture employs about two-thirds of the labor force, accounts for 37 percent of the GNP and is responsible for half of exports. Still, the sector is doing little to generate wealth among the poor. In South Asia agriculture generates 27 percent of the GNP but also has little impact on reducing inequality.

For developing countries as a whole, per capita agricultural production increased by 40 percent between 1980 and 2001, but growth was uneven. China, for example, quadrupled the value of its agricultural output and overtook the United States as the world's largest agricultural producer. Likewise, India tripled its agricultural output. In sub-Saharan Africa, however, agricultural production fell by about 5 percent over the same period. Africa is the only continent where the number of hungry people has increased in absolute terms between 1980 and 2000 and is projected to increase even further.

Globally the total production of foodstuffs surpasses total consumption. In 2000 the amount of grain in storage constituted nearly 1.2 years' worth of global consumption. However, for the past three years the world has produced less grain than it eats. According to the U.S. Department of Agriculture, in 2000 the shortfall was 35 million metric tons, in 2001 it was 31 million metric tons, and in 2002 it was an estimated 83 million metric tons. As a result grain stocks have dropped to the lowest levels in thirty years. In 2002 world wheat stocks were estimated at only 23 percent of annual consumption, while rice stocks were 28 percent. Corn was lowest of all at less than 15 percent; these are the lowest stocks for corn since record keeping began forty years ago. Production shortfalls are caused by low prices for producers at planting time (which cause planters to reduce the total area planted), high temperatures (which stress plants and so reduce yields), low temperatures (which delay planting or shorten growing seasons), and reduced or erratic rainfall or falling water tables (which stress or kill plants and so reduce production). With wheat and corn prices increasing by 30 percent or more in 2002 at least the first factor should be lessened until the next harvest

Increased producer prices will eventually affect prices of processed and manufactured goods as well as animal products. If the poor had a hard time buying food when prices were lower, they will have an even tougher time now. World grain prices have generally fallen since the mid-1990s with the exception of the recent upturn in wheat and corn prices. This should have put more food within the reach of the poor. But the problem of the poor and hungry is their lack of income, rather than the supply of food or its price. Markets that foster the delivery of regular food supplies at lower and more stable prices help create food security and potentially help reduce hunger. Yet the production of this food often actually reduces the income of the rural poor, who are being displaced precisely because they can no longer compete with cheaper food coming into their area. This as much as anything accounts for the large percentage of their income they must spend on food. In India stagnation in agriculture drives poor people to towns and accounts for as much as 30 percent of urban growth.

It would not take a lot to change this picture of entrenched rural poverty. A recent study covering fifty-eight developing countries concluded that a 1 percent increase in agricultural productivity locally would reduce the proportion of people living on $1 a day by 0.6 to 1.2 percent (Thirtle et al. 2002, as cited in DFID 2002). In India a recent study concluded that the average real income of small farmers rose by 90 percent and that of the landless by 125 percent due to increases in local agricultural productivity (Dev 1998, as cited in DFID 2002). Increases in income were mainly attributable to labor productivity gains linked to new technology.

Urbanization also increases global hunger. At the end of World War II only 18 percent of the population in developing countries lived in cities. By 2000 that figure had reached 40 percent, and it is expected to climb to 56 percent by 2030. About 50 percent of the urbanization is due to migration, both from abandoning agriculture and from the lure of potential jobs in cities. Few migrants to cities are able to produce any, much less most, of their food. They are at the mercy of the markets. If they cannot afford to buy, they go hungry. The truly poor on the planet can spend 75 percent of their income on food and still go hungry. Some 1.2 billion people have, on average, only 150 kilograms of food per person per year, or less than a pound a day.

Shipping the highly subsidized surpluses of developed countries to less-developed countries appears to be a generous way to improve the plight of the hungry. But the solution is not so simple: such shipments lower the value of local production and therefore the income of local producers while they reduce the demand for rural labor or at least the price paid for it. The subsidized agriculture of developed countries is not sustainable in its own right. More importantly, it does not contribute to sustainable food production systems in the developing world. Such food assistance rarely reaches those who need it most, plus it often causes the structural position of those who need it most—the rural poor—to deteriorate even more. Food assistance can undermine the ability of poor farmers to produce and sell food competitively in local markets. Instead of importing surplus produced elsewhere, the food needs to be produced where it will be consumed. If productivity in less-developed countries were boosted, there would be surpluses to sell and markets in which to sell them. This in turn could boost incomes at the local level and enable more people to afford food. One of the most cost-effective ways to do this would be to reduce subsidies and market barriers in developed countries.

Consolidation of farms into ever-larger agricultural production units contributes to poverty by displacing more people every year. Through mechanization, a given unit of land employs fewer people as well. Those who are employed in rural areas tend to own little or no land. Their production on small plots often subsidizes their work for larger landowners. This situation tends to occur until such workers (or their children) migrate to cities. For decades now, most children born on farms have not ended up farming.

There are a number of other social issues involved with food production. Migrant and temporary workers often account for a large percentage of production. In the United States, migrant workers produce half of all food. Such workers are fifteen times more likely to exhibit symptoms of pesticide exposure; 300,000 farm workers in the United States suffer acute pesticide poisoning each year. In addition, the average occupational fatality rates in the United States for all industries is 4.3 per 100,000 workers. However, for agriculture, forestry, and fisheries the rate is more than five times higher at 24 per 100,000.

Finally, food quality and safety are also important social issues. While it is hard to compare current levels of food contamination and overall quality with those from the past, in all likelihood most food is healthier, safer, and fresher throughout the world than at any time in history. Historically, the biggest issue has always been the quantity of food, not its quality. While that is still an issue for a significant portion of the global

population, it is no longer the paramount issue for most. More affluent consumers are probably more preoccupied with food quality than ever before. Recent food problems, including pesticide and antibiotic residues, mad cow disease, bacteria such as *E. coli* and *Salmonella*, hoof-and-mouth disease, and contaminated animal feeds have heightened consumers' concerns about their food. These concerns have generally been greater, or at least expressed more vocally, in Europe than in the United States.

Governments and Agriculture

The paramount goal for governments when it comes to agriculture is a simple one: ensure secure and inexpensive food supplies. Countries have chosen to meet this goal in a number of different ways. Governments have sponsored public works programs to increase the amount of arable land, developed infrastructure to allow products to be moved more efficiently to markets, and supported the development of technology to increase food production. They have also created subsidies based on production, or sometimes the lack of it. They have subsidized the purchase of inputs and capital and pursued a wide range of policies to encourage increased, but stable, production (Clay and von Moltke 2002).

Increasing urbanization, particularly in the developing world, complicates the issue of secure and inexpensive food supplies. Urbanization increases the demand for surplus food production from the countryside and, consequently, the pressure on rural areas to produce more. To avoid high food prices and urban unrest, most governments subsidize food prices. This has been true throughout history. Unfortunately, as discussed earlier, cheap food leads to the impoverishment of rural populations as well as to environmental degradation. Historically, the initial response to agricultural "development" has been a dramatic reduction in rural populations through migrations to cities, a process that poses huge risks of social unrest in countries like China. While this transition took a century or more in developed countries, it is happening much faster in many developing countries. Recently it has become apparent that market prices for agricultural goods can no longer support rural populations. This problem is accentuated as rural populations see the standard of living of urban populations rising and wish to emulate it.

The initial government response to this process is twofold--to continue to increase agricultural output and to seek new markets to raise the incomes of rural producers. But as other countries pursue this strategy, commodity prices deteriorate, which leads to protectionism. Another strategy is to develop new markets for organic or nontraditional crops. While this approach offers a "first-mover" advantage, other producers quickly follow suit (Clay and von Moltke 2002). The fundamental market structure is not changed. In addition, any benefits come with significant risks since the development of new markets is inherently risky due to the costs of innovation and the risks of markets not developing. For those producers who are not protected by government (increasingly the norm in developing countries, and likely to become more common in developed countries over the next twenty to thirty years), the best option is to become more efficient and sustainable. This could mean more efficient use of all inputs, reduction of waste, value-

added production, differentiation of production, selling directly to buyers or consumers, building their main asset—soil fertility—through improved management, and developing income from sources other than the sale of product .

Subsidies

More dramatic than the impoverishment of the rural poor is when an entire country cannot meet its own basic food needs. Historically, this has led to riots and political instability. No politician wants to lose his or her job because of food shortages and high prices. Nonetheless, government policies are at the heart of many food and agriculture problems. Politicians and policies, for instance, cause most famines by disrupting production (either through the confiscation of seed and other inputs or through war), by hoarding production so that it is unevenly distributed throughout the country, or by encouraging the production of nonfood crops on prime agricultural lands.

To avoid famine and economic dislocation, countries use different kinds of policies to provide incentives or disincentives for the production of different crops. Subsidies are used to encourage agricultural production. They come in many forms, but collectively they give producers the ability to sell products at prices that are lower than would otherwise be possible. Almost every developed country has found itself subsidizing agricultural producers. The exceptions—New Zealand, Australia, and to some extent Canada—represent special cases since they do not have large rural populations and their natural advantages in certain crops permit them to produce at lower costs than most other countries. Subsidies ensure agricultural surpluses under most conditions, and they allow producers in a country that subsidizes agriculture to reap benefits as producers in non-subsidizing countries are forced out of business (Clay and von Moltke 2002).

In most developed countries, and increasingly in developing ones, there appears to be no alternative to agricultural subsidies. The global population is increasingly urbanized so government priorities remain unchanged—food availability to urban workers at the lowest possible prices. Subsidies achieve that goal without generating revolts in rural areas. To date, the potential for political unrest is far more powerful than economic calculations comparing the efficiency of subsidies with that of alternative policies.

The United States began to subsidize farmers during the depression in 1929. In general, the U.S. government guarantees market prices for key agricultural products. The 2002 farm bill increased future subsidy payments precisely when there was increasing awareness of the negative impacts of subsidies and discussions about ways to reduce them. The United States also spends some $659 million per year to promote its agricultural products and exports. This is more than just selling corn, wheat, and soybeans. It also entails giving $1.6 million to McDonald's to promote Chicken McNuggets in Singapore and $11 million to Pillsbury to promote its Doughboy brand internationally (Kimbrell 2002).

According to the OECD, global agricultural subsidies amounted to about U.S.$311 billion annually in 2001 (OECD 2002a). The United Nations estimates that the costs in

lost revenues to poor countries amount to some $50 billion per year. That sum effectively offsets the entire $50 billion annually in development assistance from all sources.

Developing countries are unable to subsidize their agriculture in the same manner. However, as developing countries become more urban, their governments—given a choice between higher incomes for agricultural producers and lower food prices for urban dwellers—unhesitatingly pick the latter. Rural populations do not overthrow governments, particularly democratic ones. Urban populations do (Clay and von Moltke 2002).

Agricultural subsidies in rich countries reduce production costs or artificially raise the prices their producers receive. These subsidies are often the difference between making and losing money. Throughout the 1970s and 1980s, U.S. subsidies represented up to 30 percent of farmer income. In 2000, subsidies represented, on average, 100 percent of net profit for farmers in Indiana. Such subsidies lead to overproduction and overexploitation of resources. They also inflate land values.

While there has tended to be a shift away from policies that tie payments directly to production, some 72 percent (down from 82 percent in the mid-1980s) of support to farmers in OECD countries still keeps producer prices above those on world markets (DFID 2002). In 1999 OECD member countries provided $283 billion in domestic agricultural production subsidies. In 2001 that figure had risen to $300 billion. The European Union's Common Agriculture Policy spends some $40 billion per year by paying some 7 million farmers subsidies linked to the amount they produce (*Power* 2002). Some 80 percent of these subsidies go to 20 percent of the producers. However, total domestic support to farmers in 2001 amounted to U.S.$93.1 billion in the European Union (OECD 2002b). This compares to $49 billion in total subsidies to farmers in the United States in 2001.

Another form of subsidies is non-recourse loans, in which governments lend money to farmers using future harvests as collateral. The loan rate is based on a set value per unit of production. This calculation assumes certain average yields as well as values for the crop. However, farmers can hold crops and wait for higher prices. Thus the farmer can sell the crop at a higher rate and repay the loan in cash, or default on the loan and forfeit the lower-value crop to the government.

Export supports, or refunds on exports, used to encourage the sale of agricultural surpluses on international markets are another form of subsidy. These also depress world prices. While this may benefit some consumers, the overall distortion in domestic markets has a negative impact on rural economies as it tends to increase poverty and food insecurity.

Finally, there are several government payments that act like subsidies. The U.S. Army Corps of Engineers spends many times more each year to maintain riverine transportation than the value of the agricultural products that come down the rivers. In addition, local governments often give financial incentives to lure agribusinesses to their areas. For

example, Seaboard Corporation located a gigantic confined hog operation in Guymon, Oklahoma, after receiving an estimated $60 million in public incentives (Kimbrell 2002).

The alternative to subsidies is to let markets function without regulation. The risks of such a strategy are numerous and large. Liberalized commodity markets are volatile. The lack of elasticity in supply can cause volatility in demand, and vice versa. This in turn can cause some producers to go bankrupt while others get bought out through consolidation. Effects at the consumer level could be even more troubling—periods of oversupply and low prices alternating with periods of undersupply and high prices. While low prices may be attractive, high prices are politically unacceptable because they create hunger. Additionally, letting existing markets function without regulation means that there will be no resources for rural conservation, since today's markets only supply goods that have market prices and these prices do not include environmental services (Clay and von Moltke 2002).

Protectionism

Contrary to popular opinion, most support to farmers occurs through government manipulation of domestic prices rather than through subsidies. According to the OECD, consumers pay about one-third more for their food than they would without government support for farmers. The question is not whether consumers pay more but who actually gets that extra money. Producers receive some of it, but traders also profit by exporting subsidized goods. Processors also benefit by using subsidized goods to manufacture products that are more competitive on global markets than those produced by companies in other countries where raw materials must be purchased at full market price. The ripple effects of subsidies and market protection throughout the economy can be significant.

Governments support their own farmers through market barriers that include tariffs and taxes on imported goods. In 1998, $456 billion worth of agricultural goods was traded across borders, a threefold increase from 1978. Tariffs on agricultural goods, however, still average about 40 percent of total sales compared with less than 10 percent for manufactured goods. Governments use quotas to regulate the volume as well as the country of origin of imports. Bananas illustrate this point. The European Union (EU) imposes strict quotas and tariffs on cheaper bananas from Latin America while allowing virtually free access to more expensive ones from former colonies in Africa, the Pacific, and the Caribbean. While the World Trade Organization (WTO) ruled against this practice, it still exists—as do similar ones for sugar and other commodities.

Trade barriers and tariffs have enormous impacts. In a report commissioned by the European Union, Nagarajan (1999) estimated that a 50 percent cut in tariffs in both developed and developing countries would generate $150 billion in increased sales of agricultural products from developing countries. At the time, the figure represented three times what those same countries received in aid from all sources. The IMF reports that developing countries lose some $30 billion to agricultural supports each year (UNCTAD/WTO 2002), and the World Bank (2000) estimates that agricultural tariffs and subsidies cause annual losses of $19.8 billion for developing countries (e.g. about 40 percent of the amount they receive in development assistance). Other estimates are even

higher. The fact that these figures are so far apart clearly demonstrates the lack of information and transparency regarding tariffs.

Tariffs imposed by developed countries on agricultural products such as meat, sugar, and dairy products from developing countries are almost five times higher than tariffs for manufactured goods (DFID 2002). High and complex tariffs, coupled with increasingly stringent formal and informal product and performance standards, limit developing countries' access to international markets. These same tariffs discourage diversification of domestic production into higher-value items and retard the development of processing facilities in the protected countries.

There are other nontariff trade barriers that affect trade as well. Sanitary requirements to prevent importation of exotic pests and diseases, for example, can be effective trade barriers not because of the standards that are required but rather because of the cost of the testing to prove that the standards have been met. For many producers and exporters in developing countries it is simply not cost-effective to attempt to compete in such markets. In the future, price will probably induce large corporations to work with producers and exporters in developing countries to help them meet these requirements.

Governments are being forced to address subsidies as they affect international trade. WTO negotiations, for example, continue to focus on the reduction or elimination of agricultural subsidies. There is also an assumption by many analysts that more open markets improve farm revenues. Analyses of other commodity markets suggest that it is unlikely that the reduction or elimination of subsidies will improve prices in the long term. In all likelihood advantages will be short-lived, and the prices paid to agricultural producers will continue their downward trend.

International Trade

Some 90 percent of agricultural production is consumed in the country of origin. While a small number of commodities are produced primarily for export, most are produced for domestic consumption. In developed countries agricultural products are often incorporated into manufactured foods or refined raw materials, which are in turn exported. Export of raw materials in the tropics is often assumed to occur primarily with large-scale plantation production of crops like bananas, sugar, coffee, tea, and rubber.

The reality, however, is somewhat different, as much of the international trade in agricultural commodities is counterintuitive. For example, developing countries are net importers for all cereals, and developed countries (with the exception of Japan) are net exporters. Production costs in developed countries tend to be lower for capital-intensive activities such as large-scale grain production. Similarly, but to a lesser extent, developing regions (with the exception of Latin America) are net importers of meat, and developed ones are net exporters (with the exception of Japan, Eastern Europe, and the former USSR).

India illustrates the complexities of international trade. One in four farmers in the world live in India. When the WTO recently forced India to open its markets, imports

quadrupled. Cheap (often subsidized) imports from the U.S. but also from Thailand and Malaysia caused prices and rural incomes to plummet. The price of coconuts fell 80 percent, coffee 60 percent, pepper 45 percent; most significantly, most domestic production of edible oil has been wiped out. Imports from the United States (soybeans) and Malaysia (palm oil) now account for 70 percent of India's vegetable oil consumption (Hines 2002).

An increased focus on agricultural exports in India is also threatening the livelihoods of the rural poor. Through small-farm consolidation and increasing mechanization, the number of people living on the land in Andhra Pradesh, for example, is expected to decline from 70 to 40 percent of the total population. In other words, about 20 million people will leave the countryside for urban areas in twenty years (Hines 2002).

A trend that has arisen in the past two decades with regard to international trade is an increase in the production and sale of differentiated products. This shift from bulk to boutique commodity production is an attempt by producers and others in the market chain to create and/or capture niche markets. The notion that any commodity produced anywhere in the world can be exchanged for any other is being challenged. Perhaps the most politicized example of this is the trade in genetically modified organisms (GMOs), discussed below in the section "Technology and Agricultural Production." Many countries and consumers are insisting that GMO products be labeled and kept separate from conventional products.

Markets are further differentiated when products are broken into different subproducts and by-products that have different markets in different parts of the world. For example, in the United States the price of dark chicken meat is less than half that for white meat. There is virtually no market for chicken heads or feet. However, in Asia the market for white and dark meat is reversed. Consequently, poultry companies in the United States sell increasing amounts of dark meat to Asia and import white meat in return. Chicken heads have large and valuable markets in countries such as Thailand, and chicken feet are prized in China.

The issue of product differentiation or segregation is not a new one. Many products have long been valued more or less depending on their variety, age, country of origin, or even the reputation of the producer. Today, such differentiation is a growing part of international markets and trade. Increasingly, producers differentiate their production and target specific markets with highly specialized goods. This has become even more important with the increased use of environmental and health certification as a marketing tool. In addition, consumers are better informed and more demanding than ever before.

Globally, companies are consolidating to achieve greater efficiency and to be more competitive in a global economy. Companies that have significant shares in all the major markets are less affected by producer subsidies and market barriers. At the same time, if the WTO is successful in dismantling those subsidies and barriers, large conglomerates will be well positioned to achieve even more significant economies of scale even as they differentiate their products.

Currency Values and Commodity Production

International currency values are little-understood factors that influence the expansion and contraction of agricultural production in many parts of the world. Currency devaluation stimulates agricultural production for export. For example, the 30 percent devaluation of the Thai baht against the U.S. dollar contributed to a 26 percent increase in Thai exports in 1998 of products such as poultry to Japan and Europe and processed goods to Japan. However, if local industries are dependent on imports, devaluation erodes their competitive advantage.

Local currency devaluations also affect imports and consumption. The August 1998 devaluation of the ruble in Russia led to a rise in the cost of imported meat and contributed to a decline in meat consumption. Over time the devaluation will stimulate meat production and a rise in supply. However, in the short term in 1998 there was a 15 percent decline in meat imports accentuating a 54 percent decline in meat consumption over the past decade. Similarly, the decline in value of the Australian dollar relative to major international currencies has helped that country to export meat and grain in world markets, but imports are now more expensive there.

Given the powerful role of China as the leading producer and importer of agricultural products, the stability of the Chinese yuan is a key issue in global trade and the stability of global agricultural production. If devaluation occurs in China for any reason, all goods will become cheaper on international markets; this will have a tremendous impact on producers of several different commodities in many different parts of the world. For example, China is the world's largest producer of cotton, wheat, rice, and tobacco; the second largest producer of corn, shrimp from aquaculture, and tea; the third largest producer of oranges; and the fourth largest producer of soybeans and sugarcane. If the Chinese yuan declines in value, these goods will be cheaper on international markets. This could encourage exports from China, making producers in other parts of the world less competitive. However, China would also be able to import fewer goods. Currently China is a net importer of corn (even though it is the second largest corn producer in the world), soybeans, rubber, and palm oil. Any decline in imports of these products will have an impact on Chinese consumers and potentially China's political stability in addition to its impact on global markets and producers around the world.

China's admission to the WTO may have impacts on agricultural production that could reverberate around the world. For example, without internal market barriers China's production of rice, wheat, and soybeans would most likely be reduced at least until they could be produced more efficiently and become competitive with producers in other parts of the world. One factor that is helping China at this time, however, is that its currency is undervalued. China also has a trade surplus, and this should provide sufficient force to maintain the yuan at its present value. But this situation can change.

The example of China demonstrates that producers around the globe are more connected than ever before. Changes in currency values in one country, particularly a large producer or consumer like China, the United States, or the European Union, have a ripple effect—even a tidal wave effect--in many other parts of the world. From the point of view of the

environment, it is important to emphasize that the main environmental impacts occur during periods of economic expansion *or* economic contraction. Either can be equally damaging.

The Regulatory Context

It is clear that governments must play a key role in reducing the environmental costs of agriculture. Current attempts at this are in large part through systems of laws and regulations. Such approaches tell producers more about what they cannot do than what they should be doing. This approach is about eliminating worse practices rather than encouraging better ones. Many environmentalists have supported government fixes because there are far fewer governments than farmers, and because governments are often located in the same place as environmentalists—capital cities. Unfortunately, this has caused many environmentalists to focus on getting the stick right rather than looking for carrots or other positive incentives that would promote desired changes.

Most countries have developed command–and-control mechanisms (a set of regulations that govern input use and performance levels of producers) to address many of the environmental problems resulting from agricultural production. For example, one area of regulation includes which pesticides are allowed, under which conditions, and in what form. Other policies support more market-based approaches to changing behavior. These include taxing pesticide use and effluent pollution and eliminating subsidies for fertilizers and fuel. The European Union and the United States both use direct producer payments (subsidies) to encourage the adoption of good practices and to pay farmers to set aside highly erodible or less suitable agricultural land. While these measures were intended to cut production (which did not happen), they did result in a number of environmental benefits.

With the possible exception of water use, few countries have developed programs to encourage the adoption of better practices that reduce environmental impacts. Even water used for irrigation is rarely priced at its true cost and consequently is often wasted. In Chile, Mexico, and California farmers are allowed to trade or sell the rights to water they have, but do not need, to other buyers such as other farmers or cities. This system encourages farmers to use their water efficiently in order to sell the surplus and generate additional income. While such systems are a good start and the conservation benefits are real, water is still not part of an open, competitive market.

By focusing on regulating the impacts of individual entities, government command-and-control regulatory systems are not effective in addressing nonpoint source pollution. Thus, while many other industries have reduced their pollution, agriculture has become the largest polluter in many countries. The U.S. Environmental Protection Agency (EPA) has confirmed that this is the case in the United States. The United Kingdom estimates that its environmental costs from farming are as high as $2.5 billion per year. Two-thirds of the cost is from air pollution—nitrous oxide and methane. In fact, nitrous oxide represents almost half of the costs of agriculture's environmental impacts in the United Kingdom (ENDS Report 2000). The European Union has begun to identify similar issues. As agriculture is increasingly identified as one of the largest polluters, the industry will

come under more regulation. Given that so much agricultural pollution is nonpoint source pollution, the overall approach to cleaning up the industry will have to focus on improving management at the landscape or ecoregional level, rather than measuring and reducing pollution from specific end-of-pipe sources, as other industries have done.

Technology and Agricultural Production

Many argue that technology will increase production and feed more people while reducing the variability as well as the environmental impacts of agricultural production. Technology has clearly been important in agriculture. As Table 1.1 indicates, productivity has been boosted considerably; most of these gains have been achieved through selective breeding, domestication, and the appropriate and timely delivery of water and other inputs.

Table 1.1
Global Productivity Increases for Crops Discussed in this Report, 1961-2000
(in kilograms per hectare)

	1961	1970	1980	1990	2000	Percentage Change 1961-2000
Bananas	10,590	11,708	13,307	13,892	16,463	55.5
Beef	11	15	17	19	21	90.9
Cashews	557	599	528	583	593	6.5
Cassava	7,406	8,486	9,129	10,300	10,611	43.3
Cocoa	288	380	377	474	459	59.4
Coffee	464	433	481	537	698	50.4
Corn	1,943	2,351	3,155	3,679	4,274	120.0
Cotton	858	1,038	1,200	1,632	1,670	94.6
Oil Palm	3,771	4,639	6,981	9,982	12,224	187.6
Oranges	13,151	15,683	18,132	15,845	17,330	31.8
Rice	1,867	2,377	2,745	3,539	3,897	108.7
Rubber	546	646	693	784	888	62.6
Salmon	NA	NA	NA	NA	NA	NA
Shrimp (farmed)	#	#	#	#	611	#
Sorghum	890	1,129	1,200	1,369	1,381	55.5
Soybeans	1,129	1,480	1,600	1,898	2,176	92.7
Sugarcane	50,268	54,765	55,302	61,629	64,071	27.5
Tea	720	771	799	1,117	1,302	80.8
Tobacco	1,052	1,237	1,349	1,534	1,610	53.2
Wheat	1,089	1,494	1,855	2,561	2,737	151.6
Wood Pulp	#	#	#	#	#	#

Source: FAO 2002.
Note: # indicates data not available.

Technology has been particularly important for improving production in non-tree crops such as corn, cotton, rice, soybeans, and wheat. Because trees take longer to develop, they take longer to improve through traditional breeding programs. In addition, most tree crop production cannot be mechanized, so less research has been undertaken on trees. Recent gains from biotechnology suggest that it might be possible to improve productivity for trees, especially plantation species. There has also been work on technology to improve cultivation efficiency as well as harvesting and reducing post-harvest losses.

Some crops appear to have reached technological plateaus, as yields have not increased for the last fifteen to twenty years. Wheat yields in the United States and Mexico have leveled off. Rice production in Japan, Korea, and China is declining. Overall productivity of cereals is flat at best. In fact, while there is still potential to increase yields of wheat, rice, and corn, overall yields from breeding have not increased for the past thirty-five years. Most increases have been achieved as farmers have realized the yield potential of the varieties they cultivate (Tilman et al. 2002).

As yields hit ceilings, farmers and agrochemical companies try to find other ways to increase overall production. Pesticides, for example, allow farmers to plant the same crops year after year rather than using fallowing or crop rotation, both of which effectively reduce average production of high-value crops by half to two-thirds.

Plant breeding can improve productivity further. More important, it can help producers address many other issues that directly affect their profits. For example, developing varieties with resistance to troublesome diseases or insects can boost yields. Diseases reduce global production by an estimated 13 percent, while insects destroy another 15 percent and weeds reduce production by 12 percent. In all, some 40 percent of production potential is lost before harvest. After harvest, another 10 percent spoils or is lost to pests (Spector 1998). In sum, half of all production potential is lost.

As technology has become more important for increasing production, farmers have become more dependent on the companies that sell seeds and chemicals. With the advent of hybrid seeds eighty years ago, commercial farmers increasingly purchased their seeds from private companies rather than saving them from the previous harvest. These companies, in turn, capture an increasing share of the value in agricultural markets.

Unfortunately, the success of single interventions in agriculture is often transitory. Improving resistance to pathogens is a good example (Tilman et al. 2002). U.S. corn varieties now have a useful lifetime of four years, half of what it was thirty years ago. Similarly, within a decade or two of introduction, agrochemicals such as herbicides, insecticides, fungicides, and antibiotics lose their effectiveness because of resistance. Insects can develop resistance to agrochemicals within a decade or so. Pathogens can become resistant within one to three years.

According to numerous analysts, the gains in agricultural productivity in the late twentieth century were largely due to improved water use, prompting significant investments in water control (e.g. dams and storage facilities). India has invested more in

water control than in any other activity, and China invests more than ten times as much in water control as agricultural research (Huang et al. 2000).

Another technological trend within agriculture is the increasing reuse of waste (both on and off farm) to replace more expensive inputs. Orange peels, sugar bagasse, blood, bone meal, undigested matter from slaughtered animals, and residues from breweries are all effective sources of low-cost feed and/or soil amendments. Recycling wastes is laudable efficiency at many levels. It may come at a price, however, at least in some instances. Feeding not fully cooked body parts of animals to other animals led to mad cow disease, for example.

Spreading sewage sludge and livestock manure on farms may also expose soil to antibiotics, growth hormones, and other drugs that harm plants (Raloff 2002). The EPA reported that farmers spread 7 million metric tons of sewage sludge (called biosolids) and 3 million metric tons of animal manure on the soil each year (Raloff 2002). Much of the manure comes from feedlots where antibiotics are used more or less routinely. The Union of Concerned Scientists estimates that 2 million pounds of veterinary antibiotics are consumed by animals in feedlots each year and 27.5 million pounds of antibiotics are used as growth promoting feed additives (Raloff 2002). The entire U.S. population, by contrast, consumes 4.5 million pounds of antibiotics annually. It takes eight days in a holding tank for 50 percent of antibiotics in manure and urine to break down. If forced air (which promotes more thorough aerobic decomposition) is used, then 70 percent can break down over the same period. Unfortunately, manure is not held this long (Raloff 2002). As a consequence, a very large amount of antibiotics are released into the environment, where it is quite likely that they will increase the resistance of bacterial pathogens.

Historically, many of the technological advances that increased agricultural production were supported by governments. In developed countries, much of that support now comes from the private sector, but globally, governments still fund about two-thirds of all agricultural research, spending about $33 billion per year, or some 1.04 percent of the value of output in the mid-1990s. Support for such research has increased by 3.6 percent per year in developing countries but only by 0.2 percent per year in developed countries (Huang et al. 2002).

Genetically Modified Organisms

In the 1990s, companies like Aventis, DuPont and Monsanto transformed agriculture with a series of large biotechnology deals. These companies used technologies from the pharmaceutical sector to create new "transgenic" seed varieties (called genetically modified organisms or GMOs) with traits that could not be engineered through conventional breeding programs. Initially, these companies lacked the existing seed lines to use as building blocks, and access to farmers who would buy their products. Therefore, they (among others) spent $8.5 billion buying seed companies and creating joint ventures not only in the United States but also in England, India, South Africa, and Brazil. Seminis, a smaller Mexican company, through a series of acquisitions went from being a small player to a world leader in vegetable seeds.

By 1998, when 33 percent of the U.S. corn crop, 55 percent of the U.S. cotton crop, and 90 percent of Argentina's soybean crop were produced from transgenic seeds, this strategy appeared to be paying off. Even so, the distribution of the technology is still not widespread. Some 96 percent of all genetically modified crops are grown in the United States, Canada, and Argentina. They are also grown increasingly in Brazil, China, and South Africa. Some 5.5 million farmers in developing countries are thought to be using genetic modification technologies (Huang et al. 2002).

Both developed and developing countries have largely been interested in the development of varieties that are insect-resistant or herbicide-tolerant or both (Huang et al. 2002). Only 1 percent of field trials for GMOs in developing countries focused on higher yields. There is some evidence that this strategy is also paying off. Herbicide-resistant soybeans in Argentina have reduced per-hectare costs of production through reduced herbicide use (Qaim and Traxler 2002). Chinese cotton farmers, using a genetically modified strain to produce the biological pesticide *Bacillus thuringiensis* (Bt), have reduced pesticide sprayings for the Asian boll worm from twenty to six times per year. These farmers can thus produce a kilogram of cotton for 28 percent less than the cost to a farmer using non-Bt varieties. Similar cost reductions have been reported in Mexico and South Africa (Huang et al. 2002). U.S. growers using Bt-modified corn saved from $7.00 to $36.25 per hectare ($2.80 to $14.50 per acre) (Carlson 1997). However, if the price of genetically modified products declines due to consumer resistance, then producer savings may be a moot point.

By 1999 consumers in Europe and Japan had made it clear that they did not want GMO crops. By 2002 even American consumers began to express concerns about GMOs, and some food manufacturers (Nestlé, Iams pet foods, Gerber, Heinz, and Frito-Lay) and retailers (e.g. McDonald's) decided not to use GMOs in their products. Several large European grain millers and traders told wheat industry leaders that they would stop buying wheat from North America if genetically modified wheat were allowed on the market; this move was subsequently echoed by Japanese and American grain millers as well (Cummings 2002). Grocery store chains are beginning to require that their meat suppliers guarantee that they do not use feeds that include genetically modified ingredients. There is, too, an increasing consensus that manufacturers should be required to label their products so consumers can tell which ones contain GMOs.

The interest in (or opposition to) labeling genetically modified food ingredients hinges, in part, on liability issues. Without labeling it is impossible to tell which products contain GMOs, thus minimizing liability exposure starting at the retail level and including manufacturers, refiners/processors, and the major grain trading companies as well. In short, when corporations do not know whether there are genetically modified ingredients in their products, they can claim plausible deniability if ever questioned by consumers. This explains why the efforts to block labeling of genetically modified ingredients are in the United States, where consumers are more litigious. Swiss Re, one of the largest reinsurers, refuses to insure any risks associated with genetically modified food. Some insurance companies have refused to insure any biotech firms against risks associated with genetic modification at any cost (Zepeda 2001).

Product Substitution

Throughout history, food crops have gained or lost popularity based on how easily they can be produced, how expensive they are, or how durable they are. Throughout the past four centuries, seeds and cuttings of food crops from all over the world have been shared with producers. Today, most farmers throughout the world have found food crops that are suited to their growing conditions and that are culturally acceptable. With improved transportation systems and increasing global trade, these food products now compete with each other, often even on local markets. This process is called product substitution. Some products are nearly perfect substitutes (cane sugar and beet sugar). Other products are functional substitutes even though their individual properties may be slightly different (e.g. corn oil for soybean oil or one kind of meat for another).

When different products have similar product characteristics but different prices, there is a much greater chance of product substitution. For example, less expensive canola oil may be purchased instead of the more expensive olive oil. In the end, however, price changes for any single product are limited by the total supply, not only of that product but of all substitute products as well.

Product substitution tends to stabilize and even lower prices. As a result, it tends to lead to more single-crop, large-scale production systems, since lower prices are more damaging to small farmers.

Parallel forms of crop substitution occur from a production point of view. Producers, for example, will grow more of one product that has an increasing market and less of another for which the market is declining. In some cases, substitutes are grown in different climates or habitats and therefore have different environmental costs. For example, palm oil substitutes for many vegetable oils, but it is best suited to the moist tropics. When the demand for palm oil increases rapidly, as it has for the past twenty years, this creates incentives for producers to move into tropical forests and convert them to oil palm plantations.

Some crops are substituted for each other as equivalents. Others are substituted for each other over time as tastes and consumer preferences change. Table 1.2 suggests that from 1961 to 2000, the area used to produce fruit and vegetable oil crops has increased more than any other type of crops, implying increases in overall markets for these products. The area utilized for the production of roots and tubers, legumes, and cereals has increased very slightly, while that used for coarse grains (e.g. barley, oats, sorghum and corn/maize) and fiber crops has actually declined. Most of the total gains in production have resulted from increased productivity per hectare.

Table 1.2 Global Areas Planted by Type of Crop, 1961-2000
(in millions of hectares)

	1961	1970	1980	1990	2000	Percentage Change 1961-2000
Total cereals	648.23	675.86	717.34	708.16	672.11	3.7
Total coarse grains[+]	328.52	334.74	335.60	329.95	304.26	-7.4
Total fiber crops	38.77	40.95	40.92	37.58	35.03	-9.7
Total fruit	24.40	28.62	32.62	41.06	48.30	98.0
Total oil crops	113.54	131.90	161.98	184.10	222.32	95.8
Total legumes	63.70	63.97	60.71	67.78	67.76	6.4
Total roots & tubers	47.61	48.19	45.95	45.95	52.70	10.7

Source: FAO 2002.
[+] Coarse grains include barley, oats, corn, and sorghum.

Table 1.3 shows that the cultivation of different categories of crops changes over time. In the case of declining production, the overall use of certain crops (e.g. oats) declined in absolute terms. In some cases, particular crops (e.g. rye) became less attractive than other substitutes. By contrast, other crops (e.g. canola, cowpeas, olives) have been planted in increasing acreage as price or demand has shifted in their favor.

A few examples from Table 1.3 illustrate these points. The production of oats, for example, declined globally as horses were replaced by machinery. More recently when oats were linked to a healthy diet demand increased, but the upsurge has not offset the loss from the declining market for animal feed. To meet U.S. demand, manufacturers had to look abroad for oat supplies. Rye has lost market share to other cereal grains such as wheat. As subsidies for sugar beets are reduced, beet producers are losing their markets to cheaper sugar from cane. Grapes and potatoes have declined in area planted but have increased phenomenally in productivity, implying that specialized producers have taken over more of the production. In addition, the number of varieties cultivated globally of both species have actually declined, indicating that substitution can also take place within a general category of food such as grapes. The area planted to olives has tripled in forty years as incomes have risen, increasing demand for olive oil instead of cheaper vegetable oils. The area planted to cowpeas has nearly quadrupled in the same period because it is a fast-maturing crop, a cheap source of vegetable protein, and it requires little water or other inputs and therefore can be produced in much of the world. In short, cowpeas have performed well and have been planted by farmers as a food crop instead of other crops that had been grown in the past.

Table 1.3 Global Area Planted to Comparative Crops of Interest, 1961-2000
(in millions of hectares)

	1961	1970	1980	1990	2000	Percentage Change 1961-2000
Canola	6.28	8.21	10.98	17.59	25.72	309.6
Coconut	5.23	6.69	8.75	10.04	11.56	121.0
Cowpeas	2.19	5.31	3.15	5.10	9.87	350.7
Grapes	9.33	9.10	9.25	8.02	7.67	-17.8
Oats	38.26	30.68	24.53	20.59	12.85	-66.4
Olives	2.61	3.39	5.13	7.48	8.05	208.4
Peanuts (groundnuts)	16.64	19.49	18.36	19.69	24.29	46.0
Potatoes	22.15	20.77	18.76	17.59	19.94	-10.0
Rye	30.25	19.23	16.11	16.61	9.75	-67.8
Sugar beets	6.93	7.59	8.87	8.66	5.97	-13.9

Source: FAO 2002.

From Farm to Supermarket

Globally, consumers are sending clearer signals than ever before about what they want in their food—higher quality as well as healthier, safer, and tastier products. This is sending signals throughout the market chain stretching from the consumer, to the grocery store, to the food manufacturer, to the farm. Most companies in the food industry are currently exploring different ways to insure that they have more control over the production processes for agricultural commodities as well as overall product quality. Certification is one way to do this, as is ownership of an increasing portion of the market chain. In some instances companies are developing their own producer guidelines, which producers who want to sell products to them are required to follow.

Some consumers are turning to organic products to meet their desire for healthier, safer, and tastier products. In 2000 the global market for certified organic products reached $20 billion, about 40 percent of it in the United States. Organic food is the fastest growing food sector, but it still has a long way to grow before it captures significant market share. For example, in Denmark where organic production has the largest overall market share, it still represents only 4 percent of sales.

Even though organic products cost more, consumers seem to be willing to pay for them. In general the unit cost of organic production is higher than for conventional agriculture. In the United States, for example, organic soybeans are twice the price of conventional soybeans. Farmers in the United Kingdom reportedly receive twice as much for organic wheat as conventional wheat, but much of the income is a subsidy from the government. One thing is clear: As organic markets grow, the price paid to producers will fall, as with conventional agriculture. Put another way, today's conventional product price will be

tomorrow's organic price premium. And the scale of the individual units of production will increase.

Electronic or e-commerce food sales are becoming more common. Rabobank in the Netherlands estimates that by 2003 some 10 percent of the world's $4 trillion in agriculture production will be traded on-line. In 1999 Walnut Acres, one of the largest organic food processors and distributors in the United States, increased its sales directly to consumers from 7 percent through catalogues to 27 percent over the Internet in only nine months (David Cole, personal communication). So far, however, electronic business-to-consumer sales have been far less than expected.

The main on-line sales in the food industry, as in most others, are between businesses. This is because electronic sales are far more efficient than other types of sales, which can involve more human error. The major issue that must be addressed is how to make sales more efficient while still being able to track products back to the producer so that issues of production quality, production practices, and pesticide residues can be addressed sufficiently to meet consumer concerns. In short, while it is increasingly important for each product to have a clear chain of custody, the product must also be efficiently stored and retrieved, handled, and sold. While two-dimensional bar codes can provide a few thousand bits of information, at this time there is no easy way to use a bar code on bulk commodities. In fact, the very thing that makes food products commodities—their ease of movement and substitutability—makes them difficult to trace back to the source. It is likely that benign markers may be developed to mix with commodities, but so far that has not happened. Demand, however, will very likely cause effective tracing systems for commodities to be developed very soon.

Horizontal and Vertical Integration

Since the 1990s, there has been tremendous consolidation in all aspects of the food industry market chain—from input suppliers to producers to processors, manufacturers, and retailers. Consolidation of these industries has tended to concentrate power in the hands of fewer players.

According to *The Economist* (2000), much of the pressure on agrochemical and seed companies to drop or at least label GMO products has come from a smaller number of more important retailers as a result of the growth and consolidation of the retail industry. For example, five companies control two-thirds of the grocery business in Germany. Some 70 percent of all Swiss now shop in a single chain every week. The two largest French supermarkets have merged. Nearly half of the largest supermarkets in the United States have been involved in buyouts or mergers since 2000.

The larger the retailer, the more leverage it has over its suppliers, not just on price but also on quality, timing of delivery, and even conditions of production. Because of improved product codes and electronic checkout scanners, retailers now have exact information about consumer purchasing patterns and not just survey data. This information can be used to convince manufacturers to comply with consumer

preferences. Depending on the product (e.g. nuts, fresh fruits or vegetables), retailers can sometimes buy directly from producers.

In addition to retail-level consolidation there has also been consolidation in food manufacturing and distribution. In 2002 Unilever bought Bestfoods, Philip Morris/Kraft announced its intentions to buy Nabisco, and General Foods announced its intention to buy Pillsbury. The top ten food companies in the world are listed by total sales in Table 1.4.

Table 1.4 International Food Companies Ranked by Annual Sales, 1999

Company	Annual Sales
Nestlé	$35.1 billion
Kraft/Nabisco*	$34.9
Unilever/Bestfoods*	$32.4
General Mills/Pillsbury	$12.6
PepsiCo	$11.6
Groupe Danone	$9.8
ConAgra/International Home Foods*	$9.6
H.J. Heinz	$9.4
Sara Lee	$8.0
Kellogg	$7.0

Note: * indicates pending mergers.

An interesting fact about the consolidation of these food companies is that they are all publicly held, which means that they have the additional challenge of pleasing their shareholders as well as their customers. This is a significant shift from the smaller, family-owned businesses that dominated the food industry after World War II. This also affords consumers as well as environmental organizations another significant point of leverage within the industry.

Reduction in Number of Middlemen

Consolidation is also occurring among middlemen, all the different people who handle a product between the producer and the retailer. The number of middlemen—and how significant they are for holding, moving, or transforming the item into sub-products or manufactured products—varies tremendously depending on both the agricultural product in question as well as where it is produced and consumed in the world.

As Table 1.5 demonstrates, the U.S. market for the key agricultural commodities is dominated by only twenty-one firms. Each of the commodities is controlled by only four firms, with the market share held by those four firms ranging from a low of 45 percent for turkeys to 81 percent for beef packing and 80 percent for crushed soybeans. The same three firms (Cargil, Archer Daniels Midland, and Zen Noh) account for 81 percent of all U.S. corn exports and 65 percent of all soybean exports (Hendrickson and Heffernan 2002). Grain-trading giant Cargil recently bought its rival Continental, giving the

company 42 percent of all corn and 33 percent of soybean exports from the United States. About 80 percent of all cattle are slaughtered by only four companies. Similarly, four other firms crush 80 percent of the soybeans for oil. Four firms handle 50 percent of all broiler chickens. Concentrations can occur by controlling breeding lines and in other ways as well; 90 percent of all commercial turkeys globally come from only three genetically different breeding flocks (Kimbrell 2002). Firms such as Smithfield, International Beef Processors (IBP), and Archer Daniels Midland (ADM) are not household names but they control much of the initial processing as well as the market chain between producer and retailer.

Table 1.5 Concentration of U.S. Agricultural Markets in Four Largest Companies

Market Share	Broilers (50%)	Beef Packers (81%)	Beef Feedlots* (>50%)	Pork Packers (59%)	Sheep Packers* (70%)	Turkeys (45%)	Flour Milling (61%)	Soybean Crushing (80%)	Dry Corn Milling* (57%)	Wet Corn Milling* (74%)
Tyson Foods	x	x		x						
ConAgra	x	x	x	x	x	x	x		x	
Gold Kist	x									
Pilgrim's Pride	x									
Cargil		x	x	x		x	x	x		x
Farmland Beef		x								
Continental			x							
Cactus Feeders			x							
Smithfield				x						
Superior Packing					x					
High Country					x					
Denver Lamb					x					
Hormel						x				
Pilgrim's Pride						x				
ADM[+]							x	x	x	x
General Mills							x			
Bunge								x	x	
AGP[#]								x		
IL Cereal Mills									x	
Tate and Lyle										x
CPC										x

Source: Heffernan 1994; Hendrickson and Heffernan 2002.
Note: * indicates 1994 data; all other data for 2000.
[+] Archer Daniels Midland
[#] Ag Processing Inc.

The firms that dominate the markets tend to do so for a number of different key commodities. For example, ConAgra is one of the four dominant purchasers and resellers of eight different commodities. Cargil and ADM dominate seven and four commodities, respectively. In other parts of the world the concentration of power in just a few firms is even greater, and in a number of instances the firms are the same as those companies listed in Table 1.5. For example, Dean Foods is the largest dairy processor in the United States, more than twice the size of its nearest competitor Kraft, but it was bought by Suiza in 2001 (Hendrickson and Heffernan 2002).

Some companies are attempting to enter all the different aspects of a particular agricultural sector, except for taking on the direct risk of the producer. For example, a grocery store chain might contract with farmers to produce meat or fresh produce while eliminating all the intermediaries that would normally buy and resell the product within the distribution chain. This is vertical integration. Other firms have opted for a strategy of dominating specific value-added manufacturing sectors of the food industry. For example, Table 1.5 indicates that the same companies tend to dominate the meat processing industry—including beef, pork, and poultry—in the United States.

While 1.4 billion people in the world depend on farm-saved seed as their primary source for planting, this is not true in all countries or for all commodities. Until the past decade, the world's $20 billion seed industry was highly fragmented. Much of the fragmentation was based on the fact that different companies were working on different crops in different parts of the world. But within any one country, seed supply may be highly concentrated. In the United States, for example, 40 percent of all vegetable seed is produced by one company, 75 percent of all cereal seed by five companies, 73 percent of all corn by two companies, and 70 percent of all cotton by one company. Only 47 percent of soybean seed is produced by four companies, while farmers save 25 percent of the soybean seed that is planted (Kimbrell 2002).

Many agrochemical suppliers are vertically integrated. ConAgra, the largest distributor of agricultural chemicals in North America, is also one of the largest fertilizer producers. In 1990 the company bought its way into the seed business. It owns more than 100 grain elevators (both local and terminal), 2,000 railroad cars, and 1,100 barges. ConAgra is the largest of the three firms that mill 80 percent of the wheat in North America. It is also the largest turkey producer and the second largest broiler producer in the United States. It owns and operates poultry hatcheries. In addition, it produces its own poultry feed as well as other livestock feed. It markets chicken and turkey under its Country Skillet brand and processed meat under its Banquet and Beatrice Foods brands. It also owns the Swift Butterball, Hunt's, Peter Pan, and Orville Redenbacher brands.

But ConAgra is only the second largest food processor in the United States and the fourth largest in the world. Globally, the largest food processor is Nestlé, which is followed by Philip Morris, the largest food processor (and of course the largest tobacco producer) in the United States. In 1994, Philip Morris owned such brands as General Mills, Kraft Foods, Miller Beer, Louis Rich Turkeys, and Oscar Meyer. Ten cents of every dollar spent on food in the United States went to Philip Morris (Heffernan 1994).

Increasingly, the most significant issue for producers in the food industry is vertical integration. Vertical integration poses two main issues for producers. First, it is often accompanied by a reduction of players in the market, giving producers fewer options. Second, vertical integration allows companies to control the quality of production and institute chain-of-custody monitoring from producer to consumer. This is important not only because of consumer preferences and concerns, but also because of government regulations. Vertical integration allows companies to create or match technological developments with consumer concerns. As markets become more vertically integrated, the number of producer guidelines increases. These are the production practices that

producers are required to follow in order to sell into specific markets. The practices are not necessarily environmentally sensitive, however. Producer guidelines do not necessarily encourage the creation, much less the adoption, of better practices. In fact, they often require the prophylactic use of inputs such as pesticides to prevent problems rather than to address them as they arise, and they often require increased specialization as well.

Strict compliance with producer guidelines makes sense for companies that want to ensure a steady supply of uniform food. Such guidelines can guarantee predictable results and reduce any risks of pesticide residue or other potential liabilities. While these systems have been the most common for contract farmers (both for plant and animal crops), they are becoming more widespread. Most chickens are raised according to producer guidelines in vertically integrated operations in developed countries, and pork production is moving in the same direction.

In many parts of the world, farmers are organizing themselves. This is not new. In the past, many farmers' organizations focused on selling products in bulk and buying fertilizers and other agrochemicals in bulk. Most failed because of poor management. Today, however, more cooperatives are being developed as vertically integrated businesses. In this way, farmers can add value to their products and sell them more directly to consumers. To do this effectively, producers need competent business managers, and they need to listen very carefully to consumers' wants and concerns.

The Last Agricultural Frontiers

A number of the trends outlined in this chapter are pushing agriculture into ever more remote areas on an ever-increasing scale. Product substitution and international trade make what would appear to be different commodities compete with each other in the market place (e.g. palm oil and soy oil). This means that the productivity and cost of production of one commodity can affect the price for other commodities as well. Increasingly, producers do not merely have to compete with other producers of the same commodity, but also with producers of any other commodity that can be substituted. In addition, the WTO's interpretations to date regarding international trade indicate that subsidies such as producer payments and market barriers such as tariffs will soon be a thing of the past, which will amplify the effects of substitution. Similarly, technological improvements in resource use, overall farm management, and manipulation of crop material (whether through genetic engineering or traditional breeding programs) will also tend to push the frontiers of where agriculture can be undertaken profitably.

By the early twentieth century, the global agricultural frontier had already expanded over most of the temperate areas with good growing conditions. Many of those areas were relatively quickly abandoned because they were not suited for sustained agriculture with the technologies of the day. This was true of large parts of Europe. It was also true of the more mountainous and forested areas of the eastern United States and the drier areas of the western Great Plains. Not all land is suitable for farming. The environmental costs of

farming in the wrong places with the wrong methods are quite high both for farmers and for society as a whole, as when the 1930s dust bowl put an end to cultivation in the western Great Plains. Unfortunately, many of these lessons still have not been learned in many parts of the world.

Throughout the world, most of the land that is best suited for agriculture is already in use. Further expansion is likely to occur on marginal lands that will not support sustained production and so will be degraded quickly and abandoned. The level of degradation makes such land expensive to rehabilitate, so it is usually cheaper to expand into natural habitat.

At this time, the agricultural frontier is expanding into many of the last remaining tropical forests. Much of the Amazon and the Brazilian cerrado (the flat tableland of forests and savannas in the interior of the country bordering the eastern Amazon) is succumbing to peasant agriculture, cattle ranching, soybean production, and several cash crops that are produced until the soil is exhausted and the farmers move on to clear more land. In Southeast Asia the expansion of first rice and rubber, then cocoa and coffee, and now oil palm and pulp plantations has contributed to the loss of both pristine and degraded forests. In West and Central Africa this same cycle of first oil palm and rubber and then coffee and cocoa plantations is also responsible for the conversion of large tracts of natural forests.

There are some encouraging signs that such expansion is not inevitable. These signs come from many different parts of the world and from many different actors. At the farm level, producers are finding a number of innovative ways not only to continue to farm the same land over a long period of time but also to improve production and income at the same time. While they are still definitely in the minority, the number of farmers using innovative farming practices is increasing. For example, some Brazilian farmers have found that they can convert degraded pasture into highly productive soybean, corn, and cotton rotations within five to six years by applying no-till practices that increase the organic matter in the soil. Their efforts allow them to increase their assets even more rapidly than they increase their income from soybean production. For example, degraded land is valued at $400 to $500 per hectare. Land that can produce soybeans is worth $2,000 per hectare. Producers reclaiming degraded land can increase their assets by up to $300 per hectare per year over the five to six years that it takes to rehabilitate the land. Improving the value of the degraded land can earn farmers more than the net value of the soybeans or other crops that they produce on it. Brazilians currently farm about 60 million hectares and are converting their different forests into agricultural land at a rate of about a million hectares per year. An additional 80 million hectares of land have been abandoned or degraded. Much of this land should never have been converted from natural habitat to agriculture. However, if even 15 percent could be reclaimed for agricultural use, Brazil's current rate of agricultural expansion could be sustained for twenty years without needing to clear a single hectare of natural habitat. If productivity is increased on each hectare, then the rate of expansion of cultivated land could be slowed even more and total production would still increase.

Encouraging signals are not just coming from farmers. While most governments recognize the need to maintain stable, cheap food supplies, an increasing number of politicians are beginning to question whether the current system of subsidies and market barriers is the best way to do that. They are beginning to ask, for instance, if this is a government payment for a social good, why not pay for improved environmental or social performance rather than to maintain the income level of producers? The income levels of farmers could be maintained by payments for maintaining watershed quality or carbon sequestration just as easily as for cotton, corn, or soybeans.

Similarly, many within and outside government are beginning to question whether it would be more effective to use government regulation to encourage innovation in addition to insuring compliance with minimal standards. As it is, the focus is on what could be called the Tiger Woods approach to government: finding a new stick of a different size to solve every problem. Many are asking whether government can also have carrots in its bag of solutions.

Finally, the private sector itself is beginning to send messages to agricultural producers about what it wants and does not want. As a result of recent food scares in Europe, many of the world's largest food companies are now beginning to work with their suppliers at all levels to insure product quality and safety. Inevitably this implies not just product testing but also setting up production systems in which there is reduced risk of product quality being compromised in the first place. Many of these companies are developing their own producer guidelines. There is a tremendous potential to reduce environmental and social costs through the appropriate development and adoption of such guidelines.

Changes in investment strategies also have the potential to reduce the environmental and social costs of agriculture. It is now apparent to most investors that companies that are better managed, even with the same financial rating, will have better returns both in the short term and over time. This is true of agriculture and aquaculture as much as any other business. For that reason investors and insurers are interested in developing screens that will allow them to evaluate the management capacity of potential borrowers or claimants to reduce risk.

There is more momentum now from all sides—from the producers themselves as well as consumers, buyers, investors, insurers, and governments—to reduce the social and environmental costs of agriculture while making it more financially viable. So if everyone is interested in this, what is holding it up? Simply put, it is the boundaries of existing ways of thinking by producers, food companies, banks, and governments. People are trying to address aspects of this problem where they see them, where they have easy access to make some changes, and where they have the most leverage. Unfortunately, not enough people are working across political and commercial boundaries to bring about an effective transformation of agriculture.

Serious environmental issues remain to be addressed, as the next chapter will discuss. There are serious social and political issues as well. As the Oromo people of Ethiopia say, "You can't wake a person who is pretending to sleep." People can no longer ignore

the problems conventional agriculture poses to life on Earth or the likely scenarios of where it is headed if left to business as usual.

When I was a child in Missouri, people used to say, "If you don't know where you're going any road will get you there." Producers, consumers, corporations, and regulators may not agree on every goal or technique, but they can surely agree on where they do not want to go. This book is an attempt to create a discussion about where agriculture should go and some of the ways that might be used to get there.

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