KEY ISSUE 4

Why Do Farmers Face Economic Difficulties?

- Challenges for Farmers in Developing Countries
- Challenges for Farmers in Developed Countries
- Strategies to Increase the World's Food Supply
- Sustainable Agriculture

Learning Outcome 10.4.1

Describe the impact of population growth and trade on farming in developing countries.

Commercial farmers in developed countries and subsistence farmers in developing countries face comparable challenges. Farmers in both developing and developed countries have difficulty generating enough income to continue farming. The underlying reasons, though, are different. Commercial farmers can produce a surplus of food, whereas many subsistence farmers are barely able to produce enough food to survive.

Challenges for Farmers in Developing Countries

Two issues discussed in earlier chapters influence the choice of crops planted by subsistence farmers in developing countries:

- Subsistence farmers must feed an increasing number of people because of rapid population growth in developing countries (discussed in Chapter 2).
- Farmers who have traditionally practiced subsistence farming are pressured to grow food for export instead of for direct consumption due to the adoption of the international trade approach to development (discussed in Chapter 9).

SUBSISTENCE FARMING AND POPULATION GROWTH

Population growth influences the distribution of types of subsistence farming, according to economist Ester Boserup. It compels subsistence farmers to consider new farming approaches that produce enough food to take care of the additional people.

For hundreds if not thousands of years, subsistence farming in developing countries yielded enough food for people living in rural villages to survive, assuming that no drought, flood, or other natural disaster occurred. Suddenly in the late twentieth century, developing countries needed to provide enough food for a rapidly increasing population as well as for the growing number of urban residents who cannot grow their own food. According to Boserup, subsistence farmers increase the supply of food through intensification of production, achieved in two ways:

- **New farming methods are adopted.** Plows replace axes and sticks. More weeding is done, more manure is applied, more terraces are carved out of hillsides, and more irrigation ditches are dug (Figure 10-45). The additional labor needed to perform these operations comes from the population growth. The farmland yields more food per area of land, but with the growing population, output per person remains about the same.
- **Land is left fallow for shorter periods.** This expands the amount of land area devoted to growing crops at any given time. Boserup identified five basic stages in the intensification of farmland:
  - **Forest fallow.** Fields are cleared and utilized for up to 2 years and left fallow for more than 20 years, long enough for the forest to grow back.
  - **Bush fallow.** Fields are cleared and utilized for up to 8 years and left fallow for up to 10 years, long enough for small trees and bushes to grow back.

▼ **FIGURE 10-45 INTENSIVE FARMING METHODS** Hillsides in Radi, Bhutan, are terraced into fields for intensive planting of rice.

- **Short fallow.** Fields are cleared and utilized for perhaps 2 years (Boserup was uncertain) and left fallow for up to 2 years, long enough for wild grasses to grow back.
- **Annual cropping.** Fields are used every year and rotated between legumes and roots.
- **Multi-cropping.** Fields are used several times a year and never left fallow.

Contrast shifting cultivation, practiced in regions of low population density, such as sub-Saharan Africa, with intensive subsistence agriculture, practiced in regions of high population density, such as East Asia. Under shifting cultivation, cleared fields are utilized for a couple years and then left fallow for 20 years or more. This type of agriculture supports a small population living at low density. As the number of people living in an area increases (that is, as the population density increases) and more food must be grown, fields will be left fallow for shorter periods of time. Eventually, farmers achieve the very intensive use of farmland characteristic of areas of high population density.

SUBSISTENCE FARMING AND INTERNATIONAL TRADE

To expand production, subsistence farmers need higher-yield seeds, fertilizer, pesticides, and machinery. Some needed supplies can be secured by trading food with urban dwellers. For many African and Asian countries, though, the main way to obtain agricultural supplies is to import them from other countries. However, subsistence farmers lack the money to buy agricultural equipment and materials from developed countries.

To generate the funds they need to buy agricultural supplies, developing countries must produce something they can sell in developed countries. The developing countries sell some manufactured goods (see Chapter 11), but most raise funds through the sale of crops in developed countries. Consumers in developed countries are willing to pay high prices for fruits and vegetables that would otherwise be out of season or for crops such as coffee and tea that cannot be grown in developed countries because of the climate.

In a developing country such as Kenya, families may divide by gender between traditional subsistence agriculture and contributing to international trade. Women practice most of the subsistence agriculture—that is, growing food for their families to consume—in addition to the tasks of cooking, cleaning, and carrying water from wells. Men may work for wages, either growing crops for export or at jobs in distant cities. Because men in Kenya frequently do not share the wages with their families, many women try to generate income for the household by making clothes, jewelry, baked goods, and other objects for sale in local markets.

The sale of export crops brings a developing country foreign currency, a portion of which can be used to buy agricultural supplies. But governments in developing countries face a dilemma: The more land that is devoted to growing export crops, the less that is available to grow crops for domestic consumption. Rather than help to increase productivity, the funds generated through the sale of export crops may be needed to feed the people who switched from subsistence farming to growing export crops.

Pause and Reflect 10.4.1

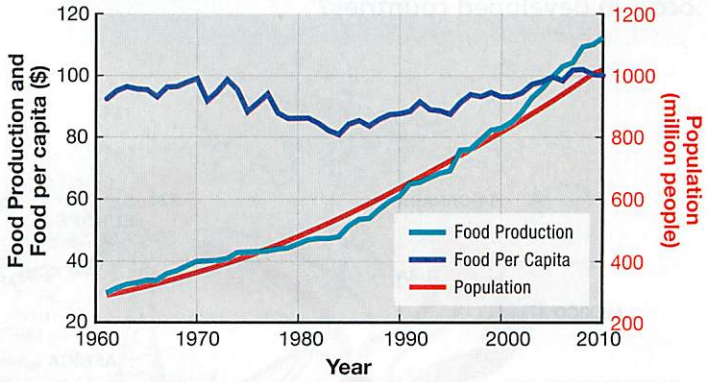
What is an example of a product available in supermarkets in the United States that was exported from a developing country?

AFRICA'S FOOD-SUPPLY STRUGGLE

Sub-Saharan Africa is struggling to keep food production ahead of population growth. Since 1961, food production has increased substantially in sub-Saharan Africa, but so has population (Figure 10-46). As a result, food production per capita has changed little in a half-century.

The threat of famine is particularly severe in the Horn of Africa and the Sahel. Traditionally, this region supported limited agriculture. With rapid population growth, farmers overplanted, and herd size increased beyond the capacity of the land to support the animals. Animals overgrazed the limited vegetation and clustered at scarce water sources.

Government policies have aggravated the food-shortage crisis. To make food affordable for urban residents, governments keep agricultural prices low. Constrained by price controls, farmers are unable to sell their commodities at a profit and therefore have little incentive to increase production.



▲ **FIGURE 10-46 POPULATION AND FOOD IN AFRICA** Food production is increasing at about the same rate as population in Africa. As a result, food production per capita is staying about the same.

DRUG CROPS

Learning Outcome 10.4.2

Understand distinctive challenges for developing countries to increase food supply.

The export crops grown in some developing countries, especially in Latin America and Asia, are those that can be converted to drugs. Cocaine and heroin, the two leading, especially dangerous drugs, are abused by 16 to 17 million people each, and marijuana, the most popular drug, is estimated to be used by 140 million worldwide:

- Cocaine is derived from coca leaf, most of which is grown in Colombia or the neighboring countries Peru and Bolivia. Most consumers are located in developed countries, especially in North America. The principal shipping route is from Colombia by sea to Mexico or other Central American countries and then by land through Mexico to the United States (Figure 10-47).
- Heroin is derived from raw opium gum, which is produced by the opium poppy plant. Afghanistan is the source of nearly 90 percent of the world's opium; most of the remainder is grown in Myanmar (Burma) and Laos. Most traffic flows from Afghanistan through Iran, Turkey, and the Balkans to Western Europe, where the largest numbers of the world's users live. A second route goes through Central Asia to Russia (Figure 10-48).
- Marijuana, produced from the *Cannabis sativa* plant, is cultivated widely around the world. The overwhelming majority of the marijuana that reaches the United States is grown in Mexico. Cultivation of *C. sativa* is not thought to be expanding worldwide, whereas cultivation of opium poppies and coca leaf are.

Pause and Reflect 10.4.2

Why does most consumption of cocaine and heroin occur in developed countries?

▲ **FIGURE 10-47 POPPY FIELD** Afghanistan is the leading producer of poppies, which are cultivated for opium production.

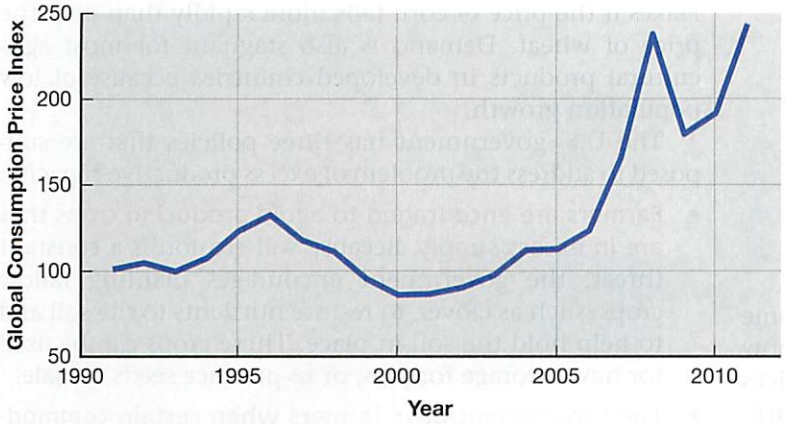
FOOD PRICES

The greatest challenge to world food supply in the twenty-first century has been food prices rather than food supply. Food prices more than doubled between 2006 and 2008, and they have remained at record high levels since then (Figure 10-49). The UN attributes the record high food prices to four factors:

- Poor weather, especially in major crop-growing regions of the South Pacific and North America
- Higher demand, especially in China and India
- Smaller growth in productivity, especially without major new "miracle" breakthroughs
- Use of crops as biofuels instead of food, especially in Latin America

On the other side of the coin, record high food prices have stimulated record high prices for prime agricultural land. Adjusting for inflation, the price of farmland in Iowa doubled from around $2,500 per acre in 2000 to $5,000 in 2010.

◀ **FIGURE 10-48 INTERNATIONAL DRUG TRAFFICKING** The main routes for heroin are from Afghanistan through Southwest Asia to Europe and through Central Asia to Russia. The main routes for cocaine are from Colombia to North America through Mexico and to Europe by sea.



▲ FIGURE 10-49 **FOOD PRICE INDEX** Worldwide food prices rose rapidly between 2006 and 2008 and have remained high since then.

SUSTAINABILITY AND INEQUALITY IN OUR GLOBAL VILLAGE

Asian Carp and Chicago's Economy

The growth of aquaculture has led to the farming of nonnative species. One example is the Asian carp, which were imported to the United States in the 1970s to stock a fish farm in Arkansas. Flooding allowed the carp to escape the farm and enter U.S. waterways. Fast-growing and voracious eaters, Asian carp can grow to over 45 kilograms (100 pounds) (Figure 10-50). Once in the waterways, the extremely aggressive Asian carp have competed successfully with native fish for food and habitat, and they have even attacked people fishing in small boats. Asian carp have traveled up the Mississippi and Illinois rivers, and they now constitute 97 percent of the fish in these rivers. Now the Asian carp threaten to reach the Great Lakes.

The most likely point of entry into the Great Lakes for the Asian carp is through Chicago-area waterways. To connect Lake Michigan and the rest of the Great Lakes with the inland waterways of the United States, canals were constructed during the nineteenth century. The U.S. Army Corps of Engineers has installed electric barriers to try to keep the Asian carp from traveling through the canals to Lake Michigan. However, in the long run, the only effective way to keep the carp out of the Great Lakes is to shut the canals. However, the canals play a major role in the economy of the Chicago area and the United States as a whole. Barges carry petroleum, coal, and other important raw materials from domestic and international sources to factories. Shutting the canals could devastate the region's economy; estimates of the impact on Chicago's economy range from $70 million to $235 million per year.

▲ FIGURE 10-50 **ASIAN CARP** Asian carp are in the Illinois River and threaten to reach the Great Lakes through Chicago-area canals.

Challenges for Farmers in Developed Countries

Learning Outcome 10.4.3

Explain the impact of overproduction and market access on farming in developed countries.

Commercial farmers in developed countries are in some ways victims of their own success. Having figured out how to produce large quantities of food, they face low prices for their output. Government subsidies help prop up farm income, but many believe that the future health of commercial farming depends on embracing more sustainable practices.

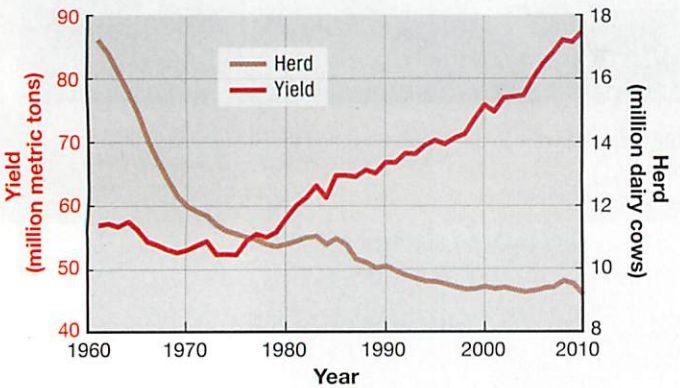
OVERPRODUCTION IN COMMERCIAL FARMING

Commercial farmers suffer from low incomes because they are capable of producing much more food than is demanded by consumers in developed countries. A surplus of food can be produced because of widespread adoption of efficient agricultural practices. New seeds, fertilizers, pesticides, mechanical equipment, and management practices have enabled farmers to obtain greatly increased yields per area of land.

The experience of dairy farming in the United States demonstrates the growth in productivity. The number of dairy cows in the United States decreased from 10.8 million to 9.1 million between 1980 and 2010. But milk production increased from 58 to 87 million metric tons. Thus, yield per cow increased 78 percent during this 30-year period, from 5.37 to 9.56 metric tons per cow (Figure 10-51).

Although the food supply has increased in developed countries, demand has remained constant because the market for most products is already saturated. In developed countries, consumption of a particular commodity may not change significantly if the price changes. Americans, for example, do not switch from Wheaties to Corn Flakes if the price of corn falls more rapidly than does the price of wheat. Demand is also stagnant for most agricultural products in developed countries because of low population growth.

▼ **FIGURE 10-51 U.S. DAIRY PRODUCTIVITY** The amount of milk produced per cow has increased rapidly in the United States, especially since the 1980s.



The U.S. government has three policies that are supposed to address the problem of excess productive capacity:

- **Farmers are encouraged to avoid producing crops that are in excess supply.** Because soil erosion is a constant threat, the government encourages planting fallow crops, such as clover, to restore nutrients to the soil and to help hold the soil in place. These crops can be used for hay or forage for pigs, or to produce seeds for sale.
- **The government pays farmers when certain commodity prices are low.** The government sets a target price for a commodity and pays farmers the difference between the price they receive in the market and the target price set by the government as a fair level for the commodity. The target prices are calculated to give farmers the same price for the commodity today as in the past, when compared to other consumer goods and services.
- **The government buys surplus production and sells or donates it to foreign governments.** In addition, low-income Americans receive food stamps in part to stimulate their purchase of additional food.

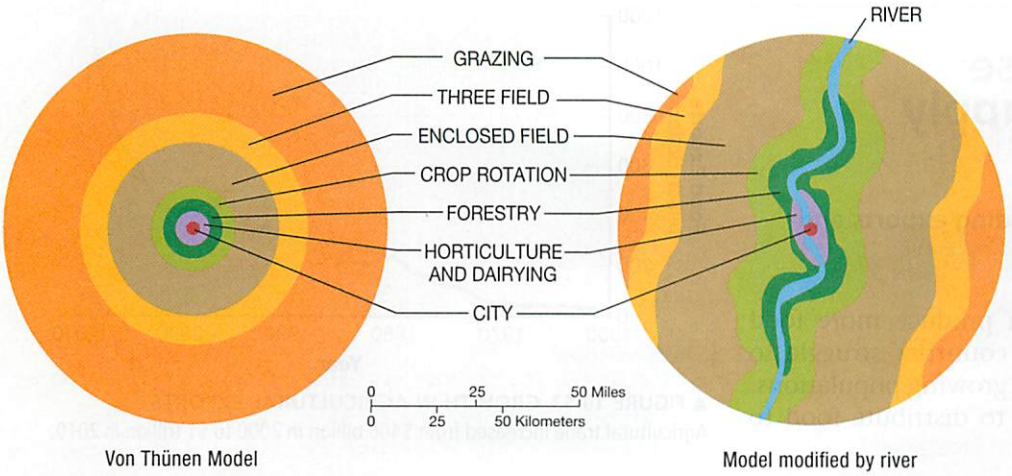
The United States has averaged about $20 billion a year on farm subsidies in recent years. Annual spending varies considerably from one year to the next. Subsidy payments are lower in years when market prices rise and production is down, typically as a result of poor weather conditions in the United States or political problems in other countries. Farming in Europe is subsidized even more than in the United States. More farmers receive subsidies in Europe, and they receive more than American farmers. The high subsidies are a legacy of a long-standing commitment by the European Union to maintain agriculture in its member states, especially in France. Supporters point to the preservation of rural village life in parts of Europe, while critics charge that Europeans pay needlessly high prices for food as a result of the subsidies.

Government policies in developed countries point out a fundamental irony in worldwide agricultural patterns: In developed regions such as North America and Europe, farmers are encouraged to grow less food, whereas developing countries struggle to increase food production to match the rate of growth in the population.

IMPORTANCE OF ACCESS TO MARKETS

Because the purpose of commercial farming is to sell produce off the farm, the distance from the farm to the market influences the farmer's choice of crop to plant. Geographers use the von Thünen model to help explain the importance of proximity to market in the choice of crops on commercial farms.

Johann Heinrich von Thünen, an estate owner in northern Germany, first proposed the model in 1826, in



▲ **FIGURE 10-52 VON THÜNEN MODEL** (left) According to the von Thünen model, in the absence of topographic factors, different types of farming are conducted at different distances from a city, depending on the cost of transportation and the value of the product. (right) von Thünen recognized that his model would be modified by site factors, such as a river in this sketch, which changes the accessibility of different land parcels to the market center. Agricultural uses that seek highly accessible locations need to locate nearer the river.

a book titled *The Isolated State* (Figure 10-52). According to this model, which geographers later modified, a commercial farmer initially considers which crops to cultivate and which animals to raise based on market location. In choosing an enterprise, the farmer compares two costs: the cost of the land and the cost of transporting products to market.

Von Thünen based his general model of the spatial arrangement of different crops on his experience as the owner of a large estate in northern Germany during the early nineteenth century. He found that specific crops were grown in different rings around the cities in the area:

- **First ring.** Market-oriented gardens and milk producers were located in the first ring out from the cities. These products are expensive to deliver and must reach the market quickly because they are perishable.
- **Second ring.** The next ring out from the cities contained wood lots, where timber was cut for construction and fuel; closeness to market is important for this commodity because of its weight.
- **Third ring.** The next ring was used for various crops and for pasture; the specific commodity was rotated from one year to the next.
- **Fourth ring.** The outermost ring was devoted exclusively to animal grazing, which requires lots of space.

The model assumed that all land in a study area had similar site characteristics and was of uniform quality, although von Thünen recognized that the model could vary according to topography and other distinctive physical conditions. For example, a river might modify the shape of the rings because transportation costs change when products are shipped by water routes rather than over roads. The model also failed to consider that social customs and government policies influence the attractiveness of plants and animals for a commercial farmer.

Although von Thünen developed the model for a small region with a single market center, the model is also applicable on a national or global scale. Farmers in relatively remote locations who wish to sell their output in the major markets of Western Europe and North America, for example, are less likely to grow highly perishable and bulky products.

The following example illustrates the influence of transportation cost on the profitability of growing wheat:

- Gross profit from sale of wheat grown on 1 hectare of land not including transportation costs:
  a. Wheat can be sold for $250 per metric ton.
  b. Yield per hectare of wheat is 4 tons.
  c. Gross profit is $1,000 per hectare ($250 per ton × 4 tons).
- Net profit from sale of wheat grown on 1 hectare of land *including* transportation costs:
  a. Cost of transporting 4 tons of wheat to market is $0.10 per kilometer.
  b. Net profit from the sale of 4 tons of wheat grown on a farm located 1,000 kilometers from the market is $900 ($1,000 gross profit – $100 for 1,000 kilometers of transport costs).
  c. Net profit from sale of 1,000 kilograms of wheat grown on a farm located 10,000 kilometers from the market is $0 ($1,000 gross profit – $1,000 for 10,000 kilometers of transport costs).

This example shows that a farmer would make a profit by growing wheat on land located less than 10,000 kilometers from the market. Beyond 10,000 kilometers, wheat is not profitable because the cost of transporting it exceeds the gross profit. These calculations demonstrate that farms located closer to market tend to select crops with higher transportation costs per hectare of output, whereas more distant farms are more likely to select crops that can be transported less expensively.

Pause and Reflect 10.4.3

If the price of wheat dropped to $200 per ton, what would be the maximum distance that the wheat could be profitably shipped?

Strategies to Increase the World's Food Supply

Learning Outcome 10.4.4

Explain the contribution of expanding exports and farmland to world food supply.

Whereas developed countries often produce more food than they need, many developing countries struggle to produce enough to feed their rapidly growing populations. Four strategies are being employed to distribute food to everyone in the world:

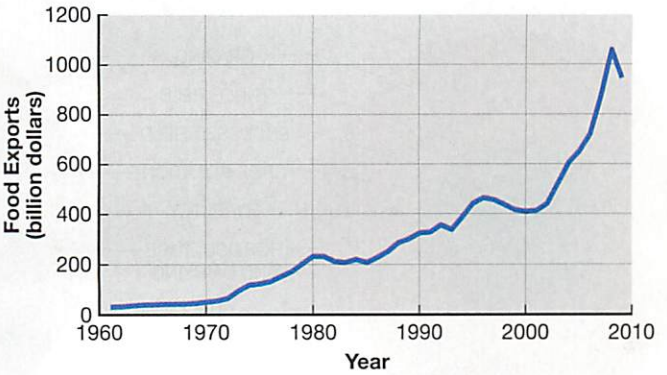
- Increasing exports from countries with surpluses
- Expanding the land area used for agriculture
- Expanding fishing
- Increasing the productivity of land now used for agriculture

Challenges underlie each of these strategies.

INCREASING EXPORTS FROM COUNTRIES WITH SURPLUSES

Trade in food has increased rapidly, especially since 2000, exceeding $1 billion for the first time in 2008 (Figure 10-53). On a global scale, agricultural products are moving primarily from the Western Hemisphere to the Eastern Hemisphere. Latin America, led by Brazil and Argentina, is the by far the leading region for export of agricultural products; North America, Southeast Asia, and the South Pacific are the other major exporting regions (Figure 10-54).

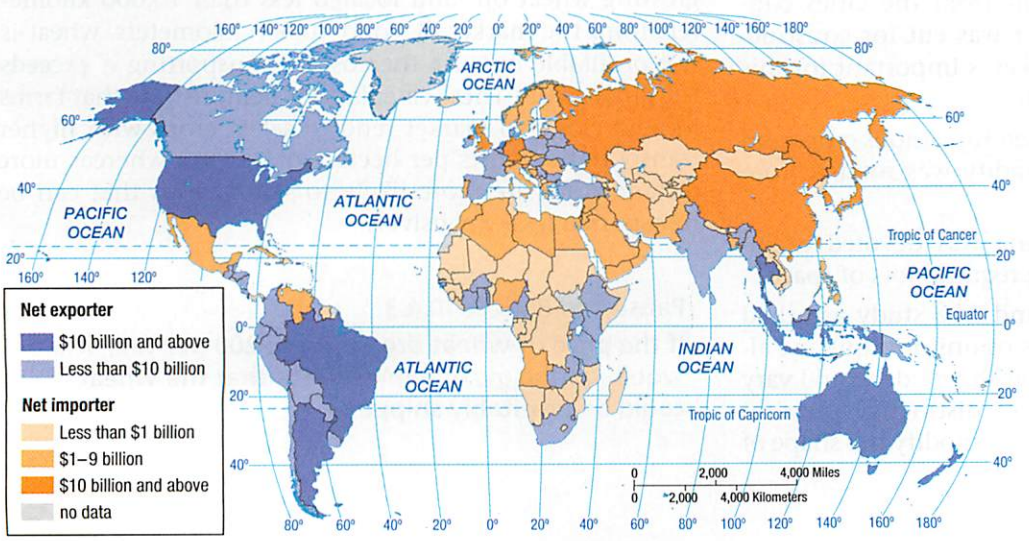
Prior to the 1980s, the only major food importing regions were Europe, East Asia, and the former Soviet Union. Historically, European countries used their colonies as suppliers of food; after they became independent countries, the former colonies sold food to Europe. Joining East Asia as net food importers were Southwest Asia and North Africa during the 1970s, South Asia and sub-Saharan Africa during the 1980s, and Central Asia in 2008. Food production was unable to keep up with rapid population growth in these regions, and as they embraced the international trade path of development, agriculture was increasingly devoted to growing export crops for sale in developed countries. Japan is by far the leading importer of food, followed by the United Kingdom, China, and Russia.



▲ **FIGURE 10-53 GROWTH IN AGICULTURAL EXPORTS** Agricultural trade increased from $400 billion in 2000 to $1 trillion in 2010.

In response to the increasing global demand for food imports, the United States passed Public Law 480, the Agricultural, Trade, and Assistance Act of 1954 (referred to as P.L.-480). Title I of the act provided for the sale of grain at low interest rates, and Title II gave grants to needy groups of people. The United States remains the world's leading exporter of grain, including nearly one-half of the world's maize exports. But the overall share of exports accounted for by the United States has declined rapidly, from 18 to 19 percent of the world total in the 1970s to 10 to 11 percent in the twenty-first century. Agricultural exports from the United States have continued to increase rapidly, but developing regions—especially Latin America and Southeast Asia—have had more rapid increases.

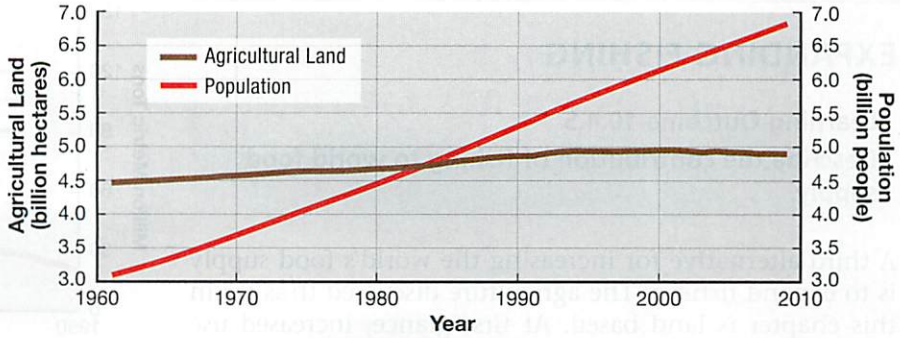
▼ **FIGURE 10-54 TRADE IN AGRICULTURAL PRODUCTS** The principal flow of agriculture in the world is from the Western Hemisphere to Europe and Asia.



EXPANDING AGRICULTURAL LAND

Historically, world food production has increased primarily by expanding the amount of land devoted to agriculture. When the world's population began to increase more rapidly in the late eighteenth and early nineteenth centuries, during the Industrial Revolution, pioneers could migrate to uninhabited territory and cultivate the land. Sparsely inhabited land suitable for agriculture was available in western North America, central Russia, and Argentina's pampas.

Two centuries ago, people believed that good agricultural land would always be available for willing pioneers. Today few scientists believe that further expansion of agricultural land can feed the growing world population. At first glance, new agricultural land appears to be available because only 11 percent of the world's land area is currently cultivated. However, in recent decades, population has increased much more rapidly than agricultural land (Figure 10-55).



▲ **FIGURE 10-55 AGRICULTURAL LAND AND POPULATION GROWTH** Land devoted to agriculture has remained virtually unchanged since 1990, whereas population has increased by more than 50 percent.

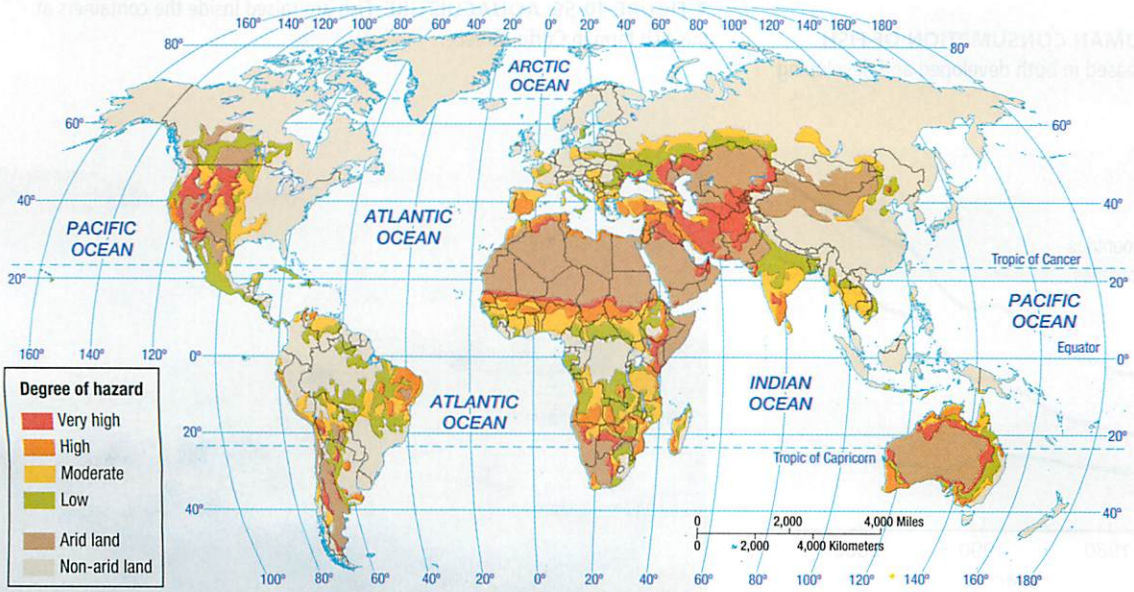
In some regions, farmland is abandoned for lack of water. Especially in semiarid regions, human actions are causing land to deteriorate to a desertlike condition, a process called **desertification** (or, more precisely, semiarid land degradation). Semiarid lands that can support only a handful of pastoral nomads are overused because of rapid population growth. Excessive crop planting, animal grazing, and tree cutting exhaust the soil's nutrients and preclude agriculture. The Earth Policy Institute estimates that 2 billion hectares (5 million acres) of land have been degraded around the world (Figure 10-56). Overgrazing is thought to be responsible for 34 percent of the total, deforestation for 30 percent, and agricultural use for 28 percent. The UN estimates that desertification removes 27 million hectares (70 million acres) of land from agricultural production each year, an area roughly equivalent to Colorado.

Excessive water threatens other agricultural areas, especially drier lands that receive water from human-built irrigation systems. If the irrigated land has inadequate drainage, the underground water level rises to the point where roots become waterlogged. The UN estimates that 10 percent of all irrigated land is waterlogged, mostly in Asia and South America. If the water is salty, it can damage plants. The ancient civilization of Mesopotamia may have collapsed in part because of waterlogging and excessive salinity in its agricultural lands near the Tigris and Euphrates rivers.

Urbanization can also contribute to reducing agricultural land. As urban areas grow in population and land area, farms on the periphery are replaced by homes, roads, shops, and other urban land uses. In North America, farms outside urban areas are left idle until the speculators who own them can sell them at a profit to builders and developers, who convert the land to urban uses. A serious problem in the United States has been the loss of 200,000 hectares (500,000 acres) of the most productive farmland, known as **prime agricultural land**, as urban areas sprawl into the surrounding countryside (see the Contemporary Geographic Tools feature).

Pause and Reflect 10.4.4

By itself, GIS can't rank the relative importance of the various factors in protecting farmland. Policymakers and the public must make these value judgments. Do you think that prime soils, significant environmental features, and high population growth should be valued the same or differently in deciding which farmland to protect?



◀ **FIGURE 10-56 DESERTIFICATION (SEMIARID LAND DEGRADATION)** The most severe problems are in northern Africa, central Australia, and the southwestern parts of Africa, Asia, North America, and South America.

EXPANDING FISHING

Learning Outcome 10.4.5

Describe the contribution of fishing to world food supply.

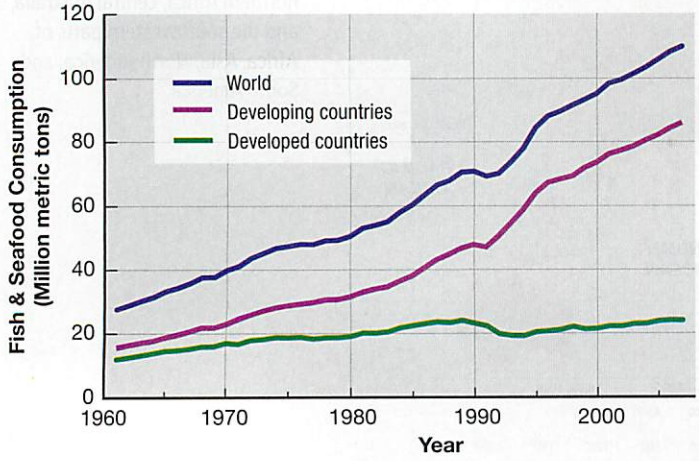
A third alternative for increasing the world's food supply is to expand fishing. The agriculture discussed thus far in this chapter is land based. At first glance, increased use of food from the sea is attractive. Oceans are vast, covering nearly three-fourths of Earth's surface and lying near most population concentrations. Historically the sea has provided only a small percentage of the world food supply.

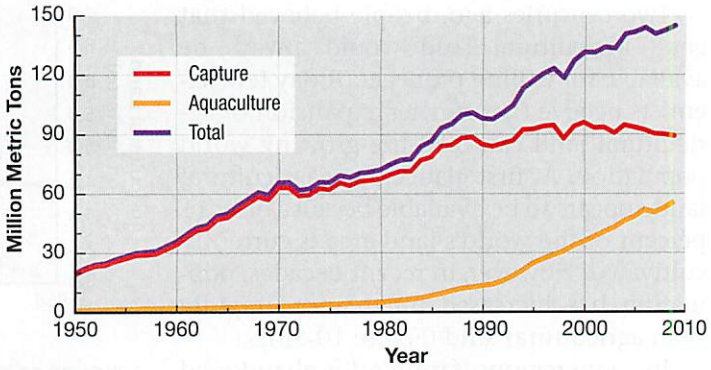
Food acquired from Earth's waters includes fish, crustaceans (such as shrimp and crabs), mollusks (such as clams and oysters), and aquatic plants (such as watercress). Water-based food is acquired in two ways:

- Fishing, which is the capture of wild fish and other seafood living in the waters.
- **Aquaculture**, or **aquafarming**, which is the cultivation of seafood under controlled conditions. (See the Sustainability and Inequality in Our Global Village feature.)

FISH CONSUMPTION. Human consumption of fish and seafood has increased from 27 million metric tons in 1960 to 110 million metric tons in 2010 (Figure 10-57). Developing countries are responsible for five-sixths of the increase. Fish consumption has increased more rapidly than population growth. During the past half-century, per capita consumption of fish has nearly doubled in both developed and developing countries, from 17 kcal per person per day in 1960 to 30 kcal per person per day in 2010. Still, fish and seafood account for only 1 percent of all calories consumed by humans (refer to Figure 10-13).

▼ **FIGURE 10-57 GROWTH IN HUMAN CONSUMPTION OF FISH**
Human consumption of fish has increased in both developed and developing regions.



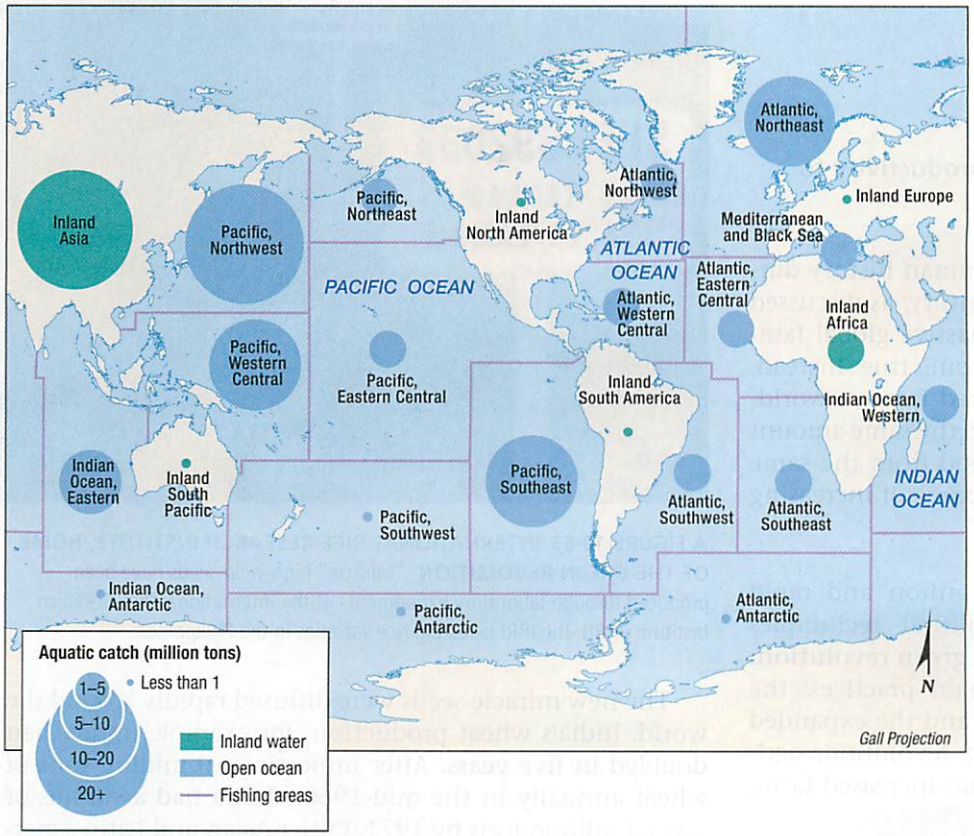


▲ **FIGURE 10-58 GROWTH IN FISH PRODUCTION**
Increased fish production has come primarily from aquaculture rather than wild capture of fish.

FISH PRODUCTION. During the past half-century, global fish production has increased from approximately 36 to 145 million metric tons (Figure 10-58). The growth results entirely from expansion of aquaculture (Figure 10-59). The capture of wild fish in the oceans and lakes has stagnated since the 1990s, despite population growth and increased demand to consume fish. The reason that production is higher than human consumption is that a large portion of the fish that is caught is converted to fish meal and fed to poultry and hogs. Only two-thirds of the fish caught from the ocean is consumed directly by humans.

The world's oceans are divided into 18 major fishing regions, including seven each in the Atlantic and Pacific oceans, three in the Indian Ocean, and the Mediterranean (Figure 10-60). Fishing is also conducted in inland waterways, such as lakes and rivers. The areas with the largest yields are the Pacific Northwest and Asia's inland waterways. China is responsible for one-third of the world's yield of fish (Figure 10-61). The other leading countries are naturally those with extensive ocean boundaries, such as Chile, Indonesia, and Peru.

▼ **FIGURE 10-59 AQUACULTURE** Fish are raised inside the containers at this fish farm in Corfu, Greece.

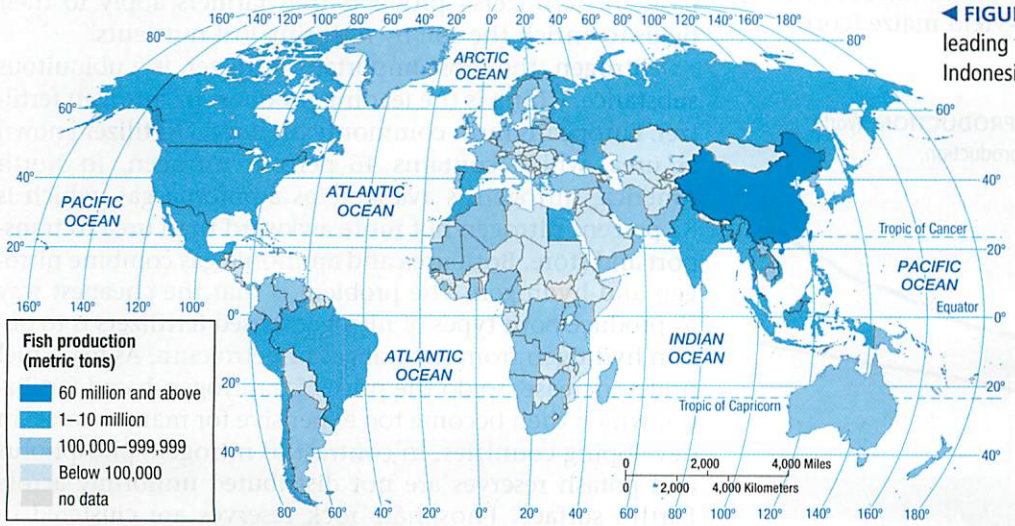


◀ **FIGURE 10-60 MAJOR FISHING REGIONS** The largest yields are in the Pacific and Asia.

OVERFISHING. Hope grew during the mid-twentieth century that increased fish consumption could meet the needs of a rapidly growing global population. However, the population of some fish species declined because they were harvested faster than they could reproduce. Overfishing has been particularly acute in the North Atlantic and Pacific oceans. Because of overfishing, the population of large predatory fish, such as tuna and swordfish, has declined by 90 percent in the past half-century. The UN estimates that one-quarter of fish stocks have been overfished and one-half fully exploited, leaving only one-fourth underfished. Consequently, the total world fish catch has remained relatively constant since the 1980s, despite population growth.

Pause and Reflect 10.4.5

Should Chicago's canals be shut to protect the Great Lakes from Asian carp? Why or why not?



◀ **FIGURE 10-61 FISH PRODUCTION** China is the leading fishing country, followed by Chile, Peru, and Indonesia.

INCREASING PRODUCTIVITY

Learning Outcome 10.4.6

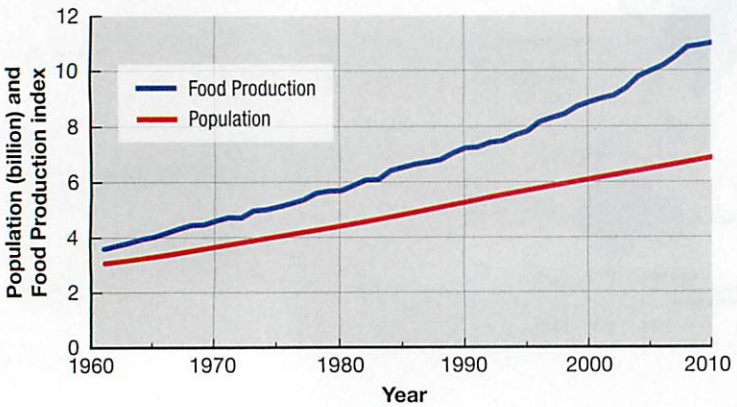
Describe the contribution of higher productivity to world food supply.

Population grew at the fastest rate in human history during the second half of the twentieth century, as discussed in Chapter 2. Many experts forecast massive global famine, but these dire predictions did not come true. Instead, new agricultural practices have permitted farmers worldwide to achieve much greater yields from the same amount of land. Worldwide, obtaining more food from the same amount of land has been the leading source of increasing the food supply.

THE GREEN REVOLUTION. The invention and rapid diffusion of more productive agricultural techniques during the 1970s and 1980s is called the **green revolution.** The green revolution involves two main practices: the introduction of new higher-yield seeds and the expanded use of fertilizers. Because of the green revolution, agricultural productivity at a global scale has increased faster than population growth (Figure 10-62).

Scientists began an intensive series of experiments during the 1950s to develop a higher-yield form of wheat. A decade later, the "miracle wheat seed" was ready. Shorter and stiffer than traditional breeds, the new wheat was less sensitive to variation in day length, responded better to fertilizers, and matured faster. The Rockefeller and Ford foundations sponsored many of the studies, and the program's director, Dr. Norman Borlaug, won the Nobel Peace Prize in 1970. The International Rice Research Institute, established in the Philippines by the Rockefeller and Ford foundations, worked to create a miracle rice seed (Figure 10-63). During the 1960s, their scientists introduced a hybrid of Indonesian rice and Taiwan dwarf rice that was hardier and that increased yields. More recently, scientists have developed new high-yield maize (corn).

▼ **FIGURE 10-62 POPULATION AND FOOD PRODUCTION** World population has increased less rapidly than food production.



▲ **FIGURE 10-63 INTERNATIONAL RICE RESEARCH INSTITUTE, HOME OF THE GREEN REVOLUTION** "Miracle" high-yield seeds have been produced through laboratory experiments at the International Rice Research Institute (IRRI). The IRRI is testing rice varieties in the Philippines.

The new miracle seeds were diffused rapidly around the world. India's wheat production, for example, more than doubled in five years. After importing 10 million tons of wheat annually in the mid-1960s, India had a surplus of several million tons by 1971. Other Asian and Latin American countries recorded similar productivity increases. The green revolution was largely responsible for preventing a food crisis in these regions during the 1970s and 1980s. But will these scientific breakthroughs continue in the twenty-first century?

To take full advantage of the new miracle seeds, farmers must use more fertilizer and machinery. Farmers have known for thousands of years that application of manure, bones, and ashes somehow increases, or at least maintains, the fertility of the land. Not until the nineteenth century did scientists identify nitrogen, phosphorus, and potassium (potash) as the critical elements in these substances that improve fertility. Today these three elements form the basis for fertilizers—products that farmers apply to their fields to enrich the soil by restoring lost nutrients.

Nitrogen, the most important fertilizer, is a ubiquitous substance. China is the leading producer of nitrogen fertilizer. Europeans most commonly produce a fertilizer known as urea, which contains 46 percent nitrogen. In North America, nitrogen is available as ammonia gas, which is 82 percent nitrogen but more awkward than urea to transport and store. Both urea and ammonia gas combine nitrogen and hydrogen. The problem is that the cheapest way to produce both types of nitrogen-based fertilizers is to obtain hydrogen from natural gas or petroleum. As fossil fuel prices increase, so do the prices for nitrogen-based fertilizers, which then become too expensive for many farmers in developing countries. In contrast to nitrogen, phosphorus and potash reserves are not distributed uniformly across Earth's surface. Phosphate rock reserves are clustered in China, Morocco, and the United States. Proven potash reserves are concentrated in Canada, Russia, and Ukraine.

Farmers need tractors, irrigation pumps, and other machinery to make the most effective use of the new miracle seeds. In developing countries, farmers cannot afford such equipment and cannot, in view of high energy costs, buy fuel to operate the equipment. To maintain the green revolution, governments in developing countries must allocate scarce funds to subsidize the cost of seeds, fertilizers, and machinery.

GENETICALLY MODIFIED FOODS. Farmers have been manipulating crops and livestock for thousands of years. The very nature of agriculture is to deliberately manipulate nature. Humans control selective reproduction of plants and animals in order to produce a larger number of stronger, hardier survivors. Beginning in the nineteenth century, the science of genetics expanded understanding of how to manipulate plants and animals to secure dominance of the most favorable traits. However, genetic modification (GM), which became widespread in the late twentieth century, marks a sharp break with the agricultural practices of the past several thousand years. Under GM, the genetic composition of an organism is not merely studied, it is actually altered; GM involves mixing genetic material of two or more species that would not otherwise mix in nature.

Worldwide, 160 million hectares—10 percent of all farmland—were devoted to genetically modified crops in 2010; 77 percent of the world's soybeans, 49 percent of cotton, and 26 percent of maize were genetically modified in 2010. GM is especially widespread in the United States: 94 percent of soybeans, 90 percent of cotton, and 88 percent of maize; usage increased rapidly during the first decade of the twenty-first century (Figure 10-64). Three-fourths of the processed food that Americans consume has at least one GM ingredient. North America was responsible for one-half of the world's genetically modified foods, and developing countries—especially in Latin America—were responsible for the other one-half.

The United States has urged sub-Saharan African countries to increase their food supply in part through increased use of GM of crops and livestock. Africans are divided on whether to accept genetically modified organisms. The positives of GM are higher yields, increased nutrition, and more resistance to pests. Genetically modified foods are also better tasting, at least to some palates. Despite these benefits, opposition to GM is strong in Africa for several reasons:

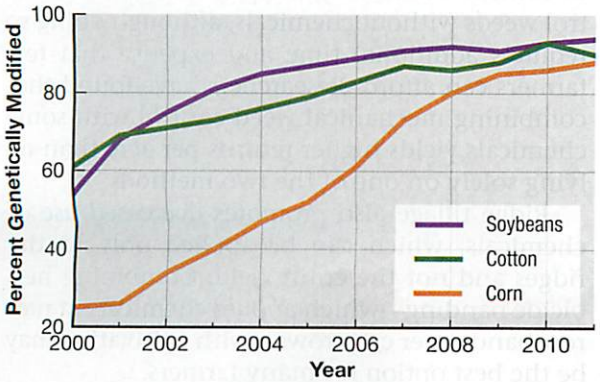
- **Health problems.** Consuming large quantities of genetically modified foods may reduce the effectiveness of antibiotics and could destroy long-standing ecological balances in local agriculture.
- **Export problems.** European countries, the main markets for Africa's agricultural exports, require genetically modified foods to be labeled. Europeans are especially strongly opposed to GM because they believe genetically modified food is not as nutritious as food from traditionally bred crops and livestock. Because European consumers shun genetically modified food, African farmers fear that if they are no longer able to certify their exports as being not genetically modified, European customers will stop buying them (Figure 10-65).
- **Increased dependence on the United States.** U.S.-based transnational corporations, such as Monsanto, manufacture most of the GM seeds. Africans fear that the biotech companies could—and would—introduce a so-called "terminator" gene in the GM seeds to prevent farmers from replanting them after harvest and require them to continue to purchase seeds year after year from the transnational corporations.

"We don't want to create a habit of using genetically modified maize that the country cannot maintain," explained Mozambique's prime minister. If agriculture is regarded as a way of life, not just a food production business, GM represents for many Africans an unhealthy level of dependency on developed countries.

Pause and Reflect 10.4.6

What are the benefits and drawbacks for sub-Saharan Africa to plant more genetically modified crops?

▼ **FIGURE 10-64 GENETICALLY MODIFIED CROPS IN THE UNITED STATES** Approximately 90 percent of major crops in the United States are genetically modified.



▼ **FIGURE 10-65 GENETICALLY MODIFIED FOOD** Genetically modified food is widespread in the United States but shunned by most consumers in Europe.

Sustainable Agriculture

Learning Outcome 10.4.7

Describe the role of sustainable agriculture in world food supply.

Some commercial farmers are converting their operations to **sustainable agriculture**, agricultural practices that preserve and enhance environmental quality. Farmers practicing sustainable agriculture typically generate lower revenues than do conventional farmers, but they also have lower costs.

An increasingly popular form of sustainable agriculture is organic farming. Worldwide, the UN classified 37 million hectares (75 million acres), or 0.6 percent of farmland, as organic in 2009. Australia was the leader, with 12 million of the hectares, or 32 percent of the worldwide total (Figure 10-66). Argentina accounted for 12 percent of the worldwide total, and the United States, China, and Brazil for 5 percent each. Three principal practices distinguish sustainable agriculture (and, at its best, organic farming) from conventional agriculture:

- Sensitive land management
- Limited use of chemicals
- Better integration of crops and livestock

SENSITIVE LAND MANAGEMENT

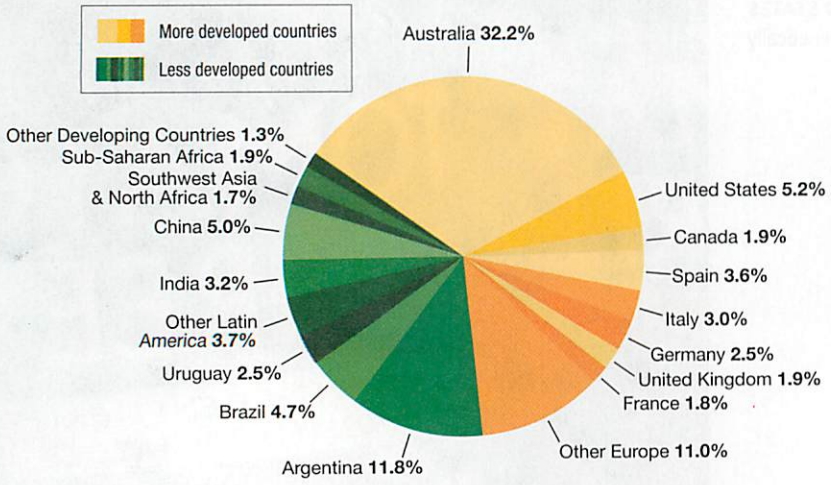
Sustainable agriculture protects soil in part through **ridge tillage**, which is a system of planting crops on ridge tops. Crops are planted on 10- to 20-centimeter (4- to 8-inch) ridges that are formed during cultivation or after harvest. A crop is planted on the same ridges, in the same rows, year after year. Ridge tillage is attractive for two main reasons: lower production costs and greater soil conservation.

Production costs are lower with ridge tillage in part because it requires less investment in tractors and other machinery than conventional planting. An area that would be prepared for planting under conventional farming with three to five tractors can be prepared for ridge tillage with only one or two tractors. The primary tillage tool is a row-crop cultivator that can form ridges. There is no need for a plow, or a field cultivator, or a 300-horsepower four-wheel-drive tractor. With ridge tillage, the space between rows needs to match the distance between wheels of the machinery. If 75 centimeters (30 inches) are left between rows, tractor tires will typically be on 150-centimeter (60-inch) centers and combine wheels on 300-centimeter (120-inch) centers. Wheel spacers are available from most manufacturers to fit the required spacing.

Ridge tillage features a minimum of soil disturbance from harvest to the next planting. A compaction-free zone is created under each ridge and in some row middles. Keeping the trafficked area separate from the crop-growing area improves soil properties. Over several years, the soil will tend to have increased organic matter, greater water-holding capacity, and more earthworms. The channels left by earthworms and decaying roots enhance drainage.

Ridge tillage compares favorably with conventional farming for yields while lowering the cost of production. Although more labor intensive than other systems, it is profitable on a per-acre basis. In Iowa, for example, ridge tillage has gained favor for production of organic and herbicide-free soybeans, which sell for more than regular soybeans.

▼ **FIGURE 10-66 DISTRIBUTION OF ORGANIC FARMING** Australia accounts for nearly one-third of the world's organic farming.



LIMITED USE OF CHEMICALS

In conventional agriculture, seeds are often genetically modified to survive when herbicides and insecticides are sprayed on fields to kill weeds and insects. These are known as "Roundup Ready" seeds because their creator, Monsanto, sells its weed killers under the brand name Roundup. Roundup Ready seeds were planted in 90 percent of all soybean fields and 70 percent of all cotton and maize (corn) fields in the United States in 2010. In addition to the adverse impacts of herbicides on soil and water quality, widespread use of Roundup Ready seeds is causing some weeds to become resistant to herbicides.

Sustainable agriculture, on the other hand, involves application of limited if any herbicides to control weeds. In principle, farmers can control weeds without chemicals, although doing so requires additional time and expense that few farmers can afford. Researchers have found that combining mechanical weed control with some chemicals yields higher returns per acre than relying solely on one of the two methods.

Ridge tillage also promotes decreased use of chemicals, which can be applied only to the ridges and not the entire field. Combining herbicide banding—which applies chemicals in narrow bands over crop rows—with cultivating may be the best option for many farmers.

INTEGRATED CROP AND LIVESTOCK

Mixed crop and livestock is a common form of farming in the United States, as discussed earlier in the chapter. But many farmers in the mixed crop and livestock region actually choose to only grow crops or raise more animals than the crops they grow can feed. They sell their crops off the farm or purchase feed for their animals from outside suppliers. Sustainable agriculture attempts to integrate the growing of crops and the raising of livestock as much as possible at the level of the individual farm. Animals consume crops grown on the farm and are not confined to small pens.

Integration of crops and livestock reflects a return to the historical practice of mixed crop and livestock farming, in which growing crops and raising animals were regarded as complementary activities on the farm. This was the common practice for centuries, until the mid-1900s, when technology, government policy, and economics encouraged farmers to become more specialized.

Sustainable agriculture is sensitive to the complexities of biological and economic interdependencies between crops and livestock:

- **Number of livestock.** The correct number, as well as the distribution, of livestock for an area is determined based on the landscape and forage sources. Prolonged concentration of livestock in a specific location can result in permanent loss of vegetative cover, so a farmer needs to move the animals to reduce overuse in some areas. Growing row crops on the more level land while confining pastures to steeper slopes will reduce soil erosion, so it may be necessary to tolerate some loss of vegetation in specific locations.
- **Animal confinement.** The moral and ethical debate over animal welfare is particularly intense regarding confined livestock production systems (Figure 10-67). Confining livestock leads to surface and ground water pollution, particularly where the density of animals is high. Expensive waste management facilities are a necessary cost of confined production systems. If animals are not confined, manure can contribute to soil fertility. However, quality of life in nearby communities may be adversely affected by the smell.
- **Management of extreme weather conditions.** Herd size may need to be reduced during periods of short- and long-term drought. On the other hand, livestock can buffer the negative impacts of low rainfall periods by consuming crops that in conventional farming would be left as failures. Especially in Mediterranean climates such as California's, properly managed grazing significantly reduces fire hazards by reducing fuel buildup in grasslands and brushlands.
- **Flexible feeding and marketing.** Flexibility in feeding livestock and sending livestock to market can help cushion farmers against trade and price fluctuations and, in conjunction with cropping operations, make more efficient use of farm labor. Feed costs are the largest single variable cost in any livestock operation. Most of the feed may come from other enterprises on a ranch, though some is usually purchased off the farm. Feed costs can be kept to a minimum by monitoring animal condition and performance and understanding seasonal variations in feed and forage quality on the farm.

▲ **FIGURE 10-67 (TOP) CONVENTIONAL VERSUS (BOTTOM) ORGANIC FARMING** Chickens are not penned up in cages on an organic farm.

Pause and Reflect 10.4.7

Are you willing to pay more for food that is organically produced? Why or why not?

CHECK-IN: KEY ISSUE 4

Why Do Farmers Face Economic Difficulties?

- ✓ **Farmers in developing countries face challenges of meeting the needs of rapid population growth and growing food for export.**
- ✓ **Farmers in developed countries face challenges of overproduction and access to markets.**
- ✓ **Four strategies for increasing the world's food supplies include increasing exports, expanding agricultural land, expanding fishing, and increasing productivity of land.**
- ✓ **Sustainable agriculture involves sensitive land management, limited use of chemicals, and better integration of crops and livestock.**