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Soil, Agriculture, and the Future of Food

Chapter Objectives

This chapter will help students:

Explain the importance of soils to agriculture, and describe the impacts of agriculture on soils

Delineate the fundamentals of soil science, including soil formation and properties

State the causes and predict the consequences of soil erosion and soil degradation

Recite the history and explain the principles of soil conservation

Identify the goals, methods, and environmental impacts of the "green revolution"

Categorize the strategies of pest management

Discuss the importance of pollination

Describe the science behind genetically modified food

Evaluate the debate over genetically modified food

Discover approaches for preserving crop diversity

Assess feedlot agriculture for livestock and poultry regarding food production and environmental quality

Assess aquaculture regarding food production and environmental quality

Evaluate sustainable agriculture

Lecture Outline

I. Central Case: Brazil's No-till Revolution

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A. In southernmost Brazil, decades of farming had used up the soil's fertility and caused erosion.

B. In the 1990s, Brazil's farmers adopted *no-tillage* farming.

C. With less soil eroding away and more organic material being added to it, the soil could hold more water and crop production increased.

D. *No-till* farming reduced costs to farmers who now used less labor and less fuel.

II. Soil: The Foundation for Agriculture

1. **Agriculture** is the practice of cultivating soil, producing crops, and raising livestock for human use and consumption.

2. As the human population increases, so does the amount of **cropland** and other resources devoted to agriculture, which currently covers 38% of Earth's land surface.

3. **Rangeland**, or pasture, is the land used for livestock.

4. Agriculture began to appear around 10,000 years ago. **Traditional agriculture** needed human and animal muscle power, hand tools, and simple machines.

5. The industrial revolution introduced large-scale fossil-fuel combustion and mechanization, leading to **industrialized agriculture** which boosted yield through increasingly efficient farming techniques.

   a. Industrialized agriculture allows more people to be fed at a high ecological price.

6. Increasing food production sustainably is necessary if we are to feed the world's rising human population.

A. **Soil** is complex and full of life.

1. Healthy **soil** is a mix of rock, organic matter, water, gases, nutrients, and microorganisms.

   a. Soil consists of about 50% mineral matter and up to 5% organic matter, and the rest is pore space filled with air or water.

2. **Parent material** is the base geological material in a location. It may be composed of volcanic deposits, glacier deposits, sediments from wind or water, or **bedrock**.

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3. The **weathering** of parent material is the first step in the formation of soil. Weathering is the physical, chemical, and biological processes that break down rocks and minerals.

4. Biological activity helps soil formation through deposition, decomposition, and accumulation of organic matter.

5. **Erosion**, the process of moving soil from one area to another, may contribute to the formation of soil in one locality even as it depletes topsoil from another.

B. A soil profile consists of layers known as **horizons**.

1. Soils can be divided into recognizable layers, or a **horizon**.

2. The cross-section of soil from bedrock to surface is the **soil profile**. The degree of weathering and concentration of organic matter decrease as one moves downward in the soil profile.

3. **Leaching** picks up minerals and particles in the soil and transports them to another location, generally downward.

4. The crucial horizon for agriculture and ecosystems is the A horizon **(topsoil)**, which consists of mostly inorganic mineral components with some organic matter and *humus*.

5. Soil can be characterized by color, texture, structure, and pH.

C. Regional differences in soil traits affect agriculture.

III. Soil Degradation and Conservation

1. Erosion can degrade ecosystems and agriculture.

2. Productive cropland is being lost at a rate of 5–7 million ha (12–17 millions acres) per year.

3. Soil degradation is caused by forest removal, cropland agriculture, and overgrazing by livestock.

4. Common problems affecting soil productivity include erosion, desertification, salinization, waterlogging, nutrient depletion, structural breakdown, and pollution.

A. Erosion carries soil away.

1. Erosion is the removal of material from one place and its transport to another by the action of wind or water.

a. *Deposition* is the arrival of eroded material at its new location.

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b. Erosion becomes a local problem because it always occurs faster than soil formation as well as removing topsoil.

c. Plant communities protect soil from wind and water erosion.

d. These include wind erosion, and four types of water erosion: *splash, sheet, rill*, and *gully*.

B. Erosion and desertification are global problems.

1. In a 2004 study, Wilkerson compared prehistoric and modern erosion rates and found that human activities move over 10 times more soil than all other natural processes combined.

2. Arid land may lose productivity by desertification. **Desertification** is a loss of more than 10% productivity due to soil erosion, soil compaction, forest removal, overgrazing, drought, salinization, climate change, depletion of water sources, or an array of other factors.

C. The Dust Bowl inspired soil conservation measures.

1. Large-scale cultivation of the southern Great Plains of the United States, combined with a drought in the 1930s, led to dust storms, destroying the land and affecting human health in the **Dust Bowl**.

   a. Prior to cultivation, deeply rooted native prairie grasses held the soil in place.

2. In response to the Dust Bowl, Congress established the Soil Conservation Service (today, known as the Natural Resources Conservation Service) in 1935 which pioneered measures to slow soil degradation and promoted soil-conservation practices.

D. Farmers can conserve soil in various ways.

1. **Crop rotation** is the practice of alternating the kind of crop grown in a particular field from one season or year to the next.

2. **Contour farming** consists of plowing furrows along the natural contours of the land.

3. **Terracing**, cutting level platforms into hillsides, is used on extremely steep terrain.

4. The planting of alternating bands of different crops across a slope is called **intercropping**.

5. **Shelterbelts** are rows of trees that are planted along the edges of fields to break the wind.

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6. With conservation or reduced tillage, plowing is bypassed as an approach to soil conservation.

E. Irrigation boosts productivity but can cause soil problems.

1. Crops that require a great deal of water can be grown with **irrigation**, artificial provision of water.

2. **Waterlogging** happens when soils become too saturated with water, damaging soil and suffocating plant roots.

3. An even more frequent problem is **salinization**, the buildup of salts in surface soil layers.

4. Salinization is easier to prevent than to correct.

F. Fertilizers boost crop yields but can be overapplied.

1. Nutrient depletion creates a need for **fertilizers** containing nutrients.

2. **Inorganic fertilizers** are mined or synthetically manufactured mineral supplements.

3. **Organic fertilizers** consist of natural materials.

4. While fertilizer use has increased crop yields, overuse is causing increasingly severe pollution problems.

G. Overgrazing can degrade soil.

1. Too much livestock on a range result in **overgrazing**, when too many animals eat too much plant cover, impeding plant growth and replacement of biomass.

2. Overgrazing can result in increased erosion, invasion of non-native plants, and compacted soil.

H. Some policies promote soil conservation.

1. Congress enacts Farm Bills with provisions requiring farmers to adopt soil conservation measures.

2. The Conservation Reserve Program (CRP) of 1985 pays farmers to remove highly erodible land from cultivation.

IV. The Race to Feed the World

A. We are producing more food per person.

1. While some people do not have access to enough food to stay healthy, others are affluent enough to consume far more than is healthy.

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a. Those who receive too few calories suffer from *undernourishment*.

b. Those who receive too few nutrients suffer from *malnutrition*.

c. Those who receive too many calories each day are *overnourished*.

2. Agricultural scientists and policymakers pursue a goal of **food security**, the guarantee of an adequate, reliable, and available food supply to all people at all times.

3. Starting in the 1960s, a number of doomsayers predicted widespread starvation and catastrophic failure of agricultural systems.

4. Instead, we have achieved dramatic increases in our carrying capacity, in part by increasing our ability to produce food.

5. This has occurred because we have devoted more energy (especially fossil fuel energy) to agriculture; by increasing the use of irrigation, fertilizer, and pesticides; by increasing the amount of cultivated land; and by developing (through crossbreeding and genetic engineering) more productive crop and livestock varieties.

6. Industrialized agriculture plants huge fields of a single type of crop, termed a **monoculture**, to increase efficiency of scale.

7. However, with grain crops, the world's staple foods, we are producing less food per person each year.

B. The "**green revolution**" boosted agricultural production.

1. Farmers in the United States had been dramatically increasing their yields using new methods and technology.

2. The transfer of technology to the developing world began in 1940 when a specially bred wheat species was introduced to Mexico.

3. Some varieties of crops yielded three or four times as much per acre as did the older varieties.

4. Developing countries imported the methods of industrialized agriculture, such as the use of synthetic fertilizers, chemical pesticides, irrigation, and fossil-fuel-powered heavy equipment.

5. From 1900 to 2000, humans expanded the world's total cultivated area by 33%, yet increased energy inputs into agriculture by 80 times.

6. The green revolution techniques have had some positive effects on the

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land by reducing the pressure to prepare more natural lands for cultivation, preventing some deforestation.

7. The green revolution techniques have had negative effects on the environment. The intensive use of water, fossil fuels, and chemical fertilizers and pesticides had extensive negative impacts in terms of pollution, salinization, and desertification.

8. The planting of monocultures has reduced biodiversity, and caused increased susceptibility of an entire crop to disease, pathogens, or insect pests. This brings the risk of catastrophic failure.

V. Pests and Pollinators

1. Throughout the history of agriculture, pests have taken advantage of our clustering food plants into agricultural fields.

2. A *pest* is any organism that damages crops that are valuable to us, and a *weed* is any plant that competes with our crops. These are subjective categories defined entirely by our own economic interests.

A. We have developed thousands of chemical pesticides.

1. Poisons that target pest organisms are termed **pesticides**. Over 900 million pounds of the active ingredients from pesticides are applied in the United States each year.

B. Pests evolve resistance to pesticides.

C. Biological control pits one organism against another.

1. **Biological control**, or **biocontrol**, operates on the principle that "the enemy of one's enemy is one's friend." We find natural enemies, or predators, of a species we consider a pest, and introduce them to an area where the pests are a problem.

2. Biological control agents themselves may become pests.

D. Integrated pest management combines methods.

1. **Integrated pest management (IPM)** uses numerous techniques, including biocontrol, chemicals, population monitoring, habitat alteration, crop rotation, transgenic crops, alternative tillage methods, and mechanical pest removal.

E. We rely on insects to pollinate crops.

1. **Pollination** is the process by which male sex cells of a plant (pollen) fertilize female sex cells of the same species of plant; it is the botanical version of sexual intercourse.

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2. While our staple grain crops are grasses that are wind-pollinated, many of our other crops depend on insects for pollination.

3. North American farmers today are dependent on European honeybees for much of their pollination. Parasitic mites are devastating the hives in recent years.

   a. In 2006, scientists raced to discover the cause for the death of entire hives known as "**colony collapse disorder.**"

4. Native pollinators are often more effective than European honeybees.

   a. Farmers and homeowners can help maintain populations of pollinating insects by reducing or eliminating pesticide use.

   b. Providing nesting sites for the bees and also food sources such as flowering plants will also increase the presence and survival of pollinators.

VI. Biotechnology and the Future of Food

A. Food can be genetically modified.

1. **Genetic engineering** is any process whereby scientists directly manipulate an organism's genetic material in the lab by adding, deleting, or changing segments of DNA.

2. **Genetically modified (GM) organisms** are organisms that have been genetically engineered using recombinant DNA technology, developed in the 1970s by scientists studying the *Escherichia coli* bacterium.

3. The creation of transgenic organisms is one type of **biotechnology**, the material application of biological science to create products derived from organisms.

4. The genetic modification of organisms by humans is nothing new.

5. However, genetic engineering creates novel combinations of genes that may not combine during traditional breeding.

B. Biotechnology is transforming the products around us.

C. What are the impacts of GM crops?

1. Some feared the new foods might be dangerous. Others were concerned that transgenes might escape and pollute ecosystems and damage nontarget organisms. Others worried that pests would evolve resistance to the supercrops and become "superpests," or that transgenes would be transferred from crops to other plants, ruining the integrity of native races of crops.

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2. We still don't know the answers, and some say that we should adopt the **precautionary principle** and not undertake a new action until the ramifications of that action are well understood.

3. Studies thus far have shown no clear answers regarding the safety of GM foods, but there are concerns that the research on GM crop safety is conducted by those industries that stand to profit from their sale.

4. Ethical issues have played a large role in the debate over GM foods because the idea of "tinkering" with the food supply seems dangerous or morally wrong.

5. The perceived lack of control over one's own food has caused concern about the domination of the global food supply by a few large businesses.

6. People of different cultures have reacted differently to issues surrounding genetically modified foods.

D. Preserving crop diversity provides insurance against failure.

1. Because accidental interbreeding can decrease the diversity of local variants, scientists argue that we need to protect areas like Oaxaca to preserve the natural genetic diversity in crop plants.

2. These varieties may confer genetic advantages against challenges to modern agriculture such as resistance to disease and pests.

3. In **seed banks**, or gene banks, institutions store seeds from crop varieties, keeping them in cold, dry conditions to encourage long-term viability.

VII. Feedlots and Aquaculture

1. The world population of domesticated animals raised for food nearly tripled between 1961 and 2000. Global meat production has increased fivefold since 1950, and per capita meat consumption has nearly doubled.

A. High consumption has led to feedlot agriculture.

1. **Feedlots**, or *factory farms*, are concentrated animal feeding operations in which animals are housed in huge warehouses or pens where energy-rich food is provided to animals living at extremely high densities.

2. Animals that are densely concentrated in feedlots will not contribute to overgrazing and soil degradation.
3. Waste from feedlots can emit strong odors, and can pollute surface water and groundwater.

4. Feedlot impacts can be minimized when properly managed.

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B. Our food choices are also energy choices.

1. The lower in the food chain our food sources are, the greater the proportion of the sun's energy we put to use as food, and the more people Earth can support.

2. Producing eggs and chicken meat requires the least space and water, while producing beef requires the most.

3. Such differences make clear that when we choose what to eat, we are also indirectly choosing how to make use of resources such as land and water.

C. Aquaculture is the fastest-growing type of food production.

1. Raising fish and shellfish on "fish farms" in controlled environments is **aquaculture**; it may be the only way to meet the demand for these foods because most fisheries are overharvested.

2. Aquaculture brings a number of benefits.

   a. Aquaculture provides a reliable source of protein for developing countries.

   b. On a small scale, aquaculture is sustainable, and is compatible with other activities.

   c. At a large scale, aquaculture helps improve a nation's food security.

   d. Aquaculture reduces fishing pressures on wild stocks.

   e. Aquaculture relies far less on fossil fuels than do fishing vessels, and is very energy efficient.

3. Aquaculture has negative environmental impacts.

   a. The dense concentrations of farmed animals can increase the incidence of disease and necessitates the use of antibiotics.

   b. Aquaculture can also produce large amounts of waste, both from the organisms being farmed and from uneaten feed.

   c. The escape of farmed animals into the environment can have negative consequences including spreading disease, outcompeting native species, and introducing new genetic material to a native population.

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VIII. Sustainable Agriculture

1. **Sustainable agriculture** is farming that does not deplete soils faster than they form and does not reduce the amount of healthy soil, clean water, and genetic diversity essential to long-term crop and livestock production.

2. *Low-input agriculture* is farming that uses smaller amounts of pesticides, fertilizers, growth hormones, water, and fossil fuel energy than is used in industrial agriculture.

3. Food growth practices that use no synthetic fertilizers or pesticides are often termed **organic agriculture**.

A. Organic agriculture is on the rise.

1. In 1990, the U.S. Congress passed the Organic Food Production Act that established national standards for organic products and facilitated the sale of *organic* food.

2. The market for organic foods increased 20% annually from 1989 to 1995, reflecting an increased demand by consumers.

3. These trends have been fueled by the desire of many consumers to reduce health risks in their diets and to support improving environmental quality.

4. Government initiatives have also spurred the growth of organic farming.

B. Locally supported agriculture is also growing.

1. Farmers' markets are more numerous as consumers rediscover the joys of fresh, locally grown produce.

2. The average food product sold in U.S. supermarkets travels at least 1,400 miles between the farm and the shelf, and is often chemically treated to preserve freshness and color.

3. Many consumers choose to form partnerships with farmers, called CSAs (community supported agriculture), where the consumers buy a share in the farm's yield.

IX. Conclusion

1. Many of the intensive agricultural practices discussed have substantial negative environmental impacts, but also have positive impacts as well.

2. It is certain that if we are to support nine billion people without further degradation of soil, water, pollinators, and other resources and

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ecosystem services which support food production, we must make a shift to more sustainable agriculture.

Key Terms

agriculture
aquaculture
bedrock
biocontrol
biological control
biotechnology
CSA (community supported agriculture)
contour farming
crop rotation
cropland
desertification
Dust Bowl
erosion
feedlots
fertilizer
food security
genetic engineering
genetically modified (GM) organisms
green revolution
horizon
industrialized agriculture
inorganic fertilizers
integrated pest management
intercropping
irrigation
leaching
monoculture
organic agriculture
organic fertilizers
overgrazing
parent material
pesticides
pollination
precautionary principle
rangeland
salinization
seed banks
shelterbelts
soil
soil profile
sustainable agriculture
terracing
topsoil
traditional agriculture
waterlogging
weathering

Teaching Tips

1. Bring soil samples to class on which students can conduct a soil texture “feel test.” In general, sandy soils feel gritty, silty soils feel like flour, and clay soils are sticky when moistened. Soils feel different because of the size of the most abundant particle type.

   The USDA categorizes particles as follows:

   Sand 2.0 mm–0.05 mm in diameter

   Silt 0.05 mm–0.002 mm in diameter

   Clay less than 0.002 mm in diameter

   To better visualize the differences in soil particle size, visualize a barrel to

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represent a sand particle, a plate to represent a silt particle, and a dime to represent a clay particle.

Because most soils are a combination of sand, silt, and clay particles, soil scientists use a more complicated method to determine the percent composition of each type. These percentage values are used in the USDA textural triangle (http://soils.usda.gov/technical/handbook/contents/part618p5.html) to determine the textural class of a soil.

A good addition to this soils lab would be to give each group of students 100 g of soil from a different location. Have them run the soil through a set of soil sieves, then weigh the fractions to determine the percent composition of the different particle types (4 or 5 types, depending on the soil sieves, ranging from gravel to clay). Have students make a pie chart or a bar graph illustrating the composition of their soil. Have students compare their results with those of other groups with soils from other areas.

2. Show the video segment "The Desert's Perfect Foods" from the *Scientific American Frontier* online video archive (www.pbs.org/saf/1110/video/watchonline.htm).

   This program illustrates how the occurrence of obesity and diabetes in the Pima and O'odham Indians of Arizona has greatly increased since the adoption of a contemporary Western diet. It also shows the people's attempts to go back to a traditional diet with foods from the desert. The Tohono O'odham Community Action Pages (www.tocaonline.org/homepage.html) has links to information about native foods and diabetes, as does the Native Seeds/SEARCH website (www.nativeseeds.org). Ask your students to research and describe some of the traditional foods that the Pima and O'odham Indians collect, prepare, and eat from their environment.

3. This chapter describes the use of pesticides in agriculture. By their nature, pesticides may pose harm to humans, pets, and the environment because they are designed to adversely affect and/or kill certain organisms. What some people do not realize is that many household products are pesticides. Therefore, it is extremely important to read the label of those products for safe use and disposal. The Consumer Labeling Initiative (CLI) and its Read the Label First program (www.epa.gov/opptintr/labeling/ campaign.htm) is an effort of the U.S. Environmental Protection Agency (EPA) to "foster pollution prevention, empower consumer choice, and improve consumer understanding of safe use, environmental, and health information on household consumer product labels." To introduce students to pesticide labels, bring some pesticide products from home such as bug sprays, flea collars, and disinfecting cleaners. Have students also bring in articles from their homes. Ask students to examine the products' labels and identify the major sections of the label that are required by the EPA.

4. Many people are concerned with the levels of pesticides and other agricultural chemicals in foods. The Food and Drug Administration conducts a Total Diet

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Study (also called the Market Basket Study) in several locations across the country, whose purpose is to determine levels of various contaminants and nutrients in foods. Sample collections are carried out four times each year in each of four geographic regions of the country, using about 280 foods purchased by FDA personnel from supermarkets, grocery stores, and fast food restaurants in three cities in the region. The regional samples are shipped to a central FDA laboratory, prepared table-ready, and combined to form a single analytical composite for each TDS food, analyzed for pesticide residues, industrial chemicals, radionuclides, toxic and nutrient elements, and folate.

Students can determine the levels of contaminants in the foods they eat by going to the FDA pesticides website (http://www.cfsan.fda.gov/~lrd/pestadd.html). About two-thirds of the way down the page are links to the Total Diet Study, which analyzes the amount of pesticides in the average diet, based upon age and sex. Download the TDS diet and import the data files into database software, such as Excel, which will allow you to sort data, perform searches, or prepare reports as desired.

5. In October 2002, the USDA National Organic Program (www.ams.usda.gov/nop/ indexIE.htm) published labeling standards for organic food that are based on the percentage of organic ingredients in a product:

    Products labeled “100 percent organic” must contain only organically produced ingredients and may display the USDA Organic Seal.

    Products labeled “organic” must consist of at least 95 percent organically produced ingredients and may display the USDA Organic Seal.

    Processed products that contain at least 70 percent organic ingredients can use the phrase “made with organic ingredients” and list up to three of the organic ingredients or food groups on the principal display panel. The USDA Seal cannot be used anywhere on the package.

    Processed products that contain less than 70 percent organic ingredients cannot use the term “organic” other than to identify the specific ingredients that are organically produced in the ingredient statement.

To investigate products, labels, and organic information, go to the Consumer’s Union Eco-label website (www.eco-labels.org/home.cfm). Have students conduct a study on the common household products that they use. From the Eco-label website, also have them click on the link that invites one to “Visit Our Virtual Kitchen,” to see the many places where eco-labels might be found

in the home, as well as providing warnings about misleading labels (e.g., click on the refrigerator, then click on the bag of ice to read comments about “natural ice”).

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Additional Resources

Websites

1. *About the Dust Bowl*, Modern American Poetry (www.english.uiuc.edu/maps/depression/dustbowl.htm).

   This website provides a brief description of the Dust Bowl, plus a map, photos, and timeline.

2. *SOILS*, Natural Resources Conservation Service (http://soils.usda.gov).

   This website is part of the National Cooperative Soil Survey, an effort by federal and state agencies to provide scientifically based soil information.

3. *National Agricultural Library*, Agricultural Research Service, United States Department of Agriculture (www.nal.usda.gov).

   This online library is a major international source for agriculture and related information.

4. *Animal Feeding Operations*, National Pollution Discharge Elimination System, U.S. Environmental Protection Agency (http://cfpub.epa.gov/npdes/home.cfm?program_id=7).

   This website is an overview of animal feeding operations and the regulations of animal waste.

5. *About Pesticides*, United States Environmental Protection Agency (www.epa.gov/pesticides/about/index.htm).

   This EPA website introduces pesticides and how they are regulated.

6. *The Leopold Center for Sustainable Agriculture*. Iowa State University. (http://www.leopold.iastate.edu/).

   The Leopold Center funds innovative research on sustainable agriculture, water quality, fiber and fruit production, marketing and policy initiatives. Their research papers and resources are available online.

Audiovisual Materials

1. *The American Experience: Surviving the Dust Bowl*, 1998, PBS Home Video distributed by WGBH (http://interactive.wgbh.org/wgbh/shop/shopamex.html).

   This program looks at America's "worst ecological disaster" that brought financial and emotional ruin to thousands of people in the Great Plains.

2. *On American Soil*, 1983, The Conservation Foundation, video distributed by Bullfrog Films (http://bullfrogfilms.com).

   This video shows the nature and extent of erosion in America.

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3. *GMOs & the Changing Face of Agriculture Series*, video series distributed by The Video Project (www.videoproject.com).

   This series of videos focuses on the spread of genetically modified organisms in our global food supply. The four films investigate the environmental, economic, and health consequences of this trend.

4. *Corporate Agriculture: Cultivating Trouble*, 2004, distributed by Films for the Humanities and Sciences (www.films.com).

   This program examines the growth of corporate factory agriculture, an industry that is capable of generating environmental, social, and cultural repercussions.

5. *Alternative Agriculture: Food for Life*, 2004, distributed by Films for the Humanities and Sciences (www.films.com).

   This program examines ecological, organic, and ethical farming as a viable alternative to industrial agriculture, and how this type of farming offers a tremendous benefit to the environment while helping to preserve traditional rural life.

6. *King Corn*. Released in October 2007, available through Public Broadcast Service, (www.PBS.org).

   This documentary film follows college friends Ian Cheney and Curtis Ellis as they move to Iowa, plant, cultivate, harvest, and market an acre of corn. The industrialized farmland of the Midwest is background for this frequently humorous film as Cheney and Ellis attempt to eat the genetically modified corn that is destined for the processors. A serious critique of subsidized agriculture that has great environmental costs to the landscape. Director Aaron Woolf also challenges GMO foods, implying that government subsidies promote obesity among Americans.

Weighing the Issues: Facts to Consider

How Would You Farm?

Facts to consider: There are two related concerns, water conservation and soil conservation. A poorly designed approach on this hill will create high runoff, removing soil through erosion. Contour farming, or more likely terracing, will be necessary to prevent serious water erosion. Terracing could allow effective irrigation on the north side. On the south slope, shelterbelts could be used to mitigate wind erosion. Soil conservation has a second component—the quality of the soil. This includes nutrients, soil fauna diversity, and the abiotic structure of the soil, i.e., the percentage of sand, clay, and the like. One strategy would be crop rotation. An additional factor is cost. For example, if no-till or reduced-tillage farming is used, the farmer may have extra herbicide or labor costs as unwanted seeds are buried alongside planted seeds. Other costs might be the work of contouring or terracing and the careful construction of irrigation.

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The Green Revolution and Population

Facts to consider: Whether or not the green revolution was successful depends on one's perspective. The green revolution increased the world's food supply and supplied food to many hungry people through crop yield improvements using high-yield crop plants. Initially, improved yield also reduced, or in some cases prevented, deforestation and habitat conversion of wild lands to agricultural use. However, increased food supplies also increased the carrying capacity of various regions, which allowed the human population to increase as well. The increased crop yields used to feed an exponentially growing human population were produced through nonsustainable farming methods with negative environmental impacts, such as increased fossil fuel use, the diversion of water for irrigation, and the application of large amounts of chemical fertilizers and pesticides. The world's population has continued to grow during the green revolution, but its growth rate has slowed. So, to some extent, the green revolution and demographic transition theory have worked together to reduce the likelihood of widespread starvation. Some countries have been working more actively than others to reduce population growth rates, and some countries have seen economic, social, and educational developments that tend to reduce birth rates.

Do You Want Your Food Labeled?

Facts to consider: This question requires an individual response. All agriculture, and hence food choices, have good and bad environmental impacts. In some cases, such as in the case of shade-grown coffee plantations, the way in which the coffee is grown has a positive effect on the flora and fauna of the ecosystem. Eating produce and meat not grown with chemical fertilizers, pesticides, and growth hormones keeps these persistent chemicals out of the environment. These farming methods are expensive, and farmers—many of whom barely break even during the year—may revert to tried-and-true farming methods that are not environmentally friendly. Purchasing power has been an effective way for groups to make their views about food preference known and to make points that have, in fact, influenced food manufacturers. GM foods may be another issue where this proves to be the case.

The Science behind the Story

Transgenic Contamination of Native Maize?

This vignette highlights that part of scientific inquiry that is not often seen by the public—the debate and arguments within the scientific community caused by controversial research.

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Original research: Researchers David Quist and Ignacio Chapela published a paper in the journal *Nature* that concluded that a transgene found in genetically modified corn had found its way into the genome of native maize and changed locations within the genome after it had entered the native maize's DNA.

Critiques: Critics claimed that the i-PCR technique was an unreliable method, and that Quist and Chapela used insufficient controls. Matthew Metz of the University of Washington and Johannes Fütterer of the Institute of Plant Science in Zurich, Switzerland, both argued that the i-PCR results showed, at the most, first-generation hybrids between transgenic and native maize. Paul Christou, editor of the journal *Transgenic Research,* and others expressed concern that Quist and Chapela may not have been careful in their laboratory technique. Letters published in *Nature* stated that there was insufficient evidence to publish the paper.

Response: Quist and Chapela acknowledged that some of their initial findings, including the i-PCR results, were probably invalid. At the same time, the researchers presented a new analysis to support their conclusions and referred to a study by the Mexican government that also found high rates of transgenic contamination.

Critique: The results of the Mexican government study were unpublished and had not been reviewed by peers.

Further developments: The debate became heated and personal both within and outside of academic circles. Opponents and supporters of GM crops leveled many personal attacks on each other as well as upon Quist and Chapela. After speaking out against a proposed partnership between his university and a biotechnology firm, Chapela was denied tenure, which was later awarded after a 3-year fight. Researchers remained divided about this issue, where the lack of scientific data, combined with high economic and environmental stakes surrounding Mexico's ban on transgenic corn, added fuel to the dispute.

Current situation: Most recently, a new study by Garcia, Snow, and others reported a large survey of seeds from Oaxacan maize, and found no evidence for transgenes. Although this seemed at first blush to contradict the Quist and Chapela findings, the authors were careful to provide several alternative explanations for the discrepancy.

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