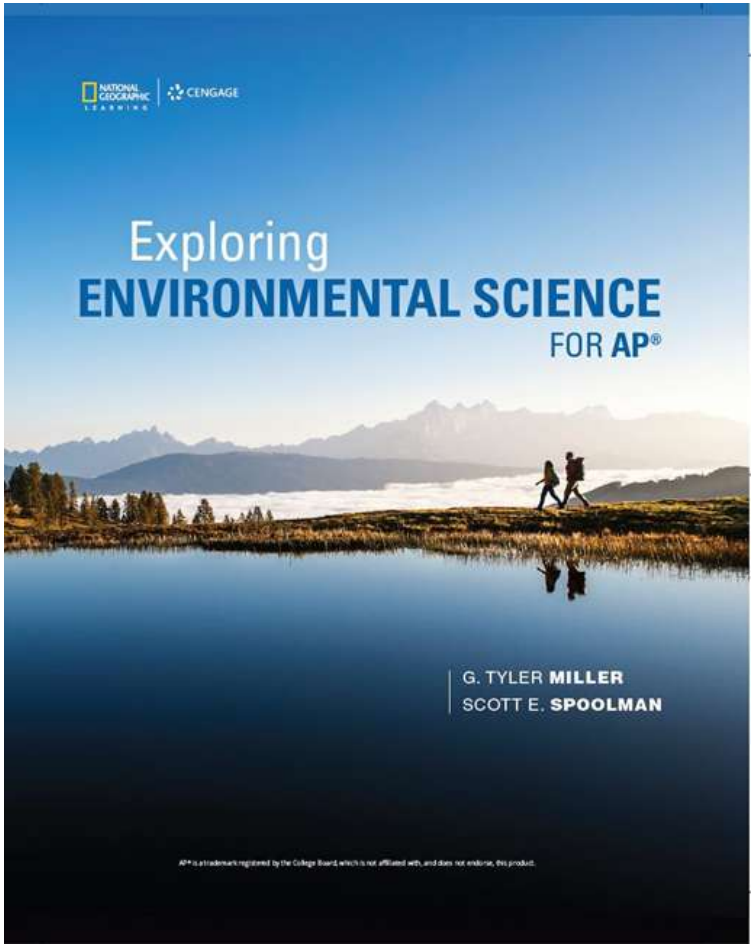
Exploring Environmental Science for AP®

1st Edition



Chapter 12
Food Production and the Environment

Core Case Study: Growing Power–An Urban Food Oasis (1 of 2)

- Food desert
  - Urban area where people have little or no easy access to nutritious food
- Growing Power, Inc. in Milwaukee, WI
  - Ecologically based farm using solar power
  - Produces 150 varieties of organic produce
  - Nutrients recycled in creative ways
  - Provides education and training in organic farming methods

Core Case Study: Growing Power–An Urban Food Oasis (2 of 2)

Courtesy of Growing Power, Inc.

12.1 Why Is Good Nutrition Important? (1 of 2)

- Many people in less-developed countries have health problems from not getting enough food
  - Many people in more-developed countries suffer health problems from eating too much
- Greatest obstacles to providing enough food for everyone
  - Poverty, war, bad weather, and climate change

12.1 Why Is Good Nutrition Important? (2 of 2)

Reuters/CORBIS

Many People Suffer from Lasting Hunger and Malnutrition (1 of 2)

- Macronutrients
  - Carbohydrates
  - Proteins
  - Fats
- Micronutrients
  - Vitamins
    - Examples: A, B, C, and E
  - Minerals
    - Examples: iron, iodine, and calcium

Many People Suffer from Lasting Hunger and Malnutrition (2 of 2)

- Chronic undernutrition
  - Not enough food to meet basic energy needs
- Chronic malnutrition
  - Not enough protein or other key nutrients
- Famine
  - Severe shortage of food
    - Crop failures due to drought, flooding, or war
  - Can cause mass starvation, many deaths, economic chaos, and social disruption

A Closer Look at Micronutrients

- Two billion people deficient in one or more vitamins and minerals
- Too little iron
  - Causes anemia
- Iodine
  - Essential for thyroid function
  - Chronic lack causes stunted growth, mental retardation, and goiter

Health Problems from Eating Too Much

- Overnutrition
  - Excess body fat from too many calories and too little exercise
- Similar health problems to those who are underfed
  - Lower life expectancy
  - Greater susceptibility to disease and illness
  - Lower productivity and life quality

Poverty Is the Root Cause of Hunger and Malnutrition

- Half the world's people struggle to survive on USD $2.25 per day
- Poverty prevents daily access to nutritious food
- Other obstacles to food security
  - War
  - Corruption
  - Bad weather
  - Climate change

12.2 How Is Food Produced?

- We have used high-input industrialized agriculture and low-input traditional agriculture to greatly increase food supplies

Food Production Has Increased Dramatically

- Three systems produce most of our food
  - Croplands produce grains
    - Primarily rice, wheat, and corn
  - Rangelands, pastures, and feedlots produce meat and meat products
  - Fisheries and aquaculture provide fish products
- Important technological advances
  - Irrigation, synthetic fertilizers, and pesticides

Industrialized Crop Production Relies on High-Input Monocultures (1 of 2)

- Industrialized agriculture
  - Heavy equipment
  - Large amounts of financial capital, fossil fuels, water, inorganic fertilizers, and pesticides
  - Single crop
  - Major goal: steadily increase crop yield
- Plantation agriculture–cash crops
  - Primarily in less-developed countries

Industrialized Crop Production Relies on High-Input Monocultures (2 of 2)

Traditional Agriculture Often Relies on Low-Input Polyculture

- Traditional subsistence agriculture
  - Human labor and draft animals for family food
- Traditional intensive agriculture
  - Higher yields through increased labor, animal manure, and water
- Polyculture
  - Several crops grown on same farm
  - Benefits over monoculture

Organic Agriculture Is on the Rise (1 of 2)

- Crops grown without synthetic pesticides or fertilizers
  - No genetically engineered seed varieties
- Animals must be raised with 100% organic feed without antibiotics or growth hormones
- More labor-intensive than conventionally produced food
  - Costs more

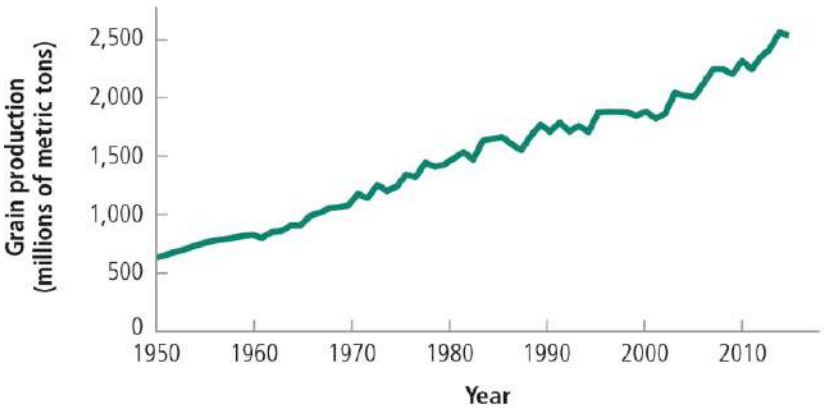
Organic Agriculture Is on the Rise (2 of 2)

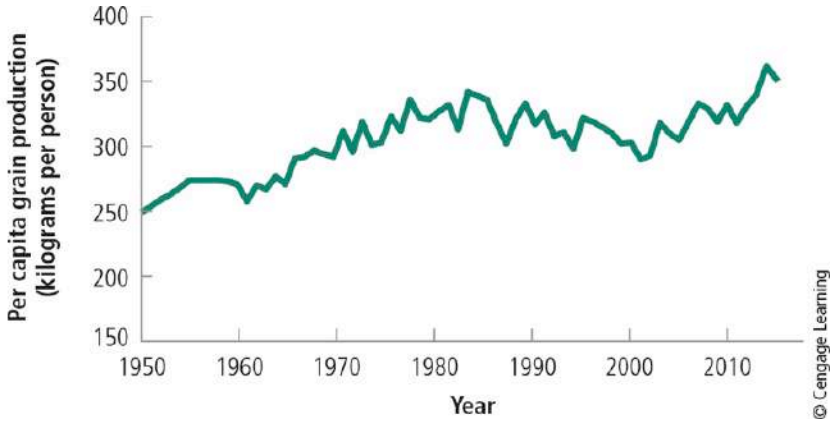
Industrialized Agriculture	Organic Agriculture
 Uses synthetic inorganic fertilizers and sewage sludge to supply plant nutrients	 Emphasizes prevention of soil erosion and the use of organic fertilizers such as animal manure and compost, but no sewage sludge, to supply plant nutrients
Makes use of synthetic chemical pesticides	Employs crop rotation and biological pest control
 Uses conventional and genetically modified seeds	 Uses no genetically modified seeds
Depends on nonrenewable fossil fuels (mostly oil and natural gas)	Reduces fossil fuel use and increases use of renewable energy such as solar and wind power for generating electricity
 Produces significant air and water pollution and greenhouse gases	 Produces less air and water pollution and greenhouse gases
Is globally export-oriented	Is regionally and locally oriented
Uses antibiotics and growth hormones to produce meat and meat products	Uses no antibiotics or growth hormones to produce meat and meat products

A Closer Look at Industrialized Crop Production (1 of 2)

- Green Revolution–increase crop yields
  - Monocultures of high-yield key crops
    - Rice, wheat, and corn
  - Large amounts of fertilizers, pesticides, water
  - Multiple cropping
- Second Green Revolution
  - Fast growing varieties of rice and wheat
- World grain production tripled between 1950 and 2014

A Closer Look at Industrialized Crop Production (2 of 2)





Case Study: Industrialized Food Production in the U.S.

- Agribusiness
  - Few giant, multinational corporations control growing, processing, distribution, and sale of food
- Food production–very efficient
  - Americans spend 9% of income on food
- Actual costs of food much higher
  - Hidden costs of subsidies, pollution, and environmental degradation

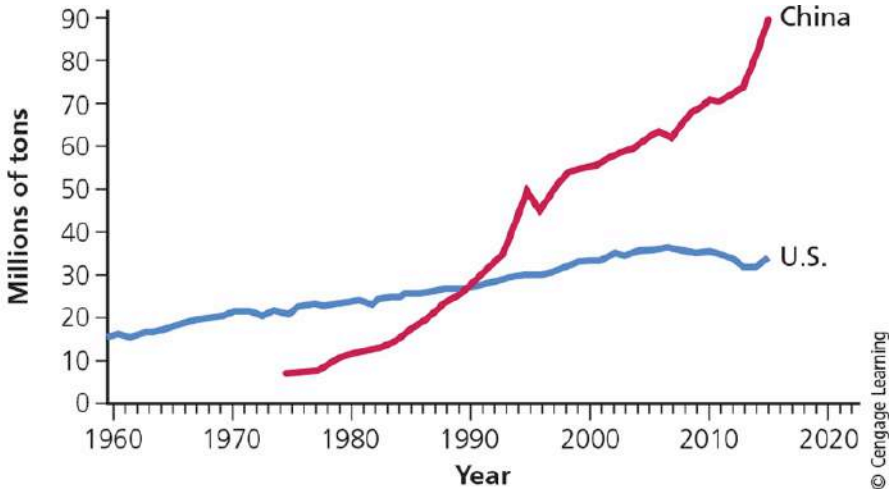
Crossbreeding and Genetic Engineering Produce New Varieties of Crops and Livestock

- First gene revolution
  - Cross-breeding through artificial selection
    - Slow process
    - Amazing results
- Genetic engineering–second gene revolution
  - Alter organism's DNA
  - Genetically modified organisms (GMOs)–transgenic organisms

Meat Consumption Has Grown Steadily (1 of 3)

- Meat production increased more than sixfold between 1950 and 2010
  - Pork, poultry, and beef top products
  - Increased demand for grain
    - Greater reliance on grain imports
    - China
- About half of the world's meat raised on rangeland
  - Half in factory farm system

Meat Consumption Has Grown Steadily (2 of 3)



Meat Consumption Has Grown Steadily (3 of 3)

PETE MCBRIDE/National Geographic Creative

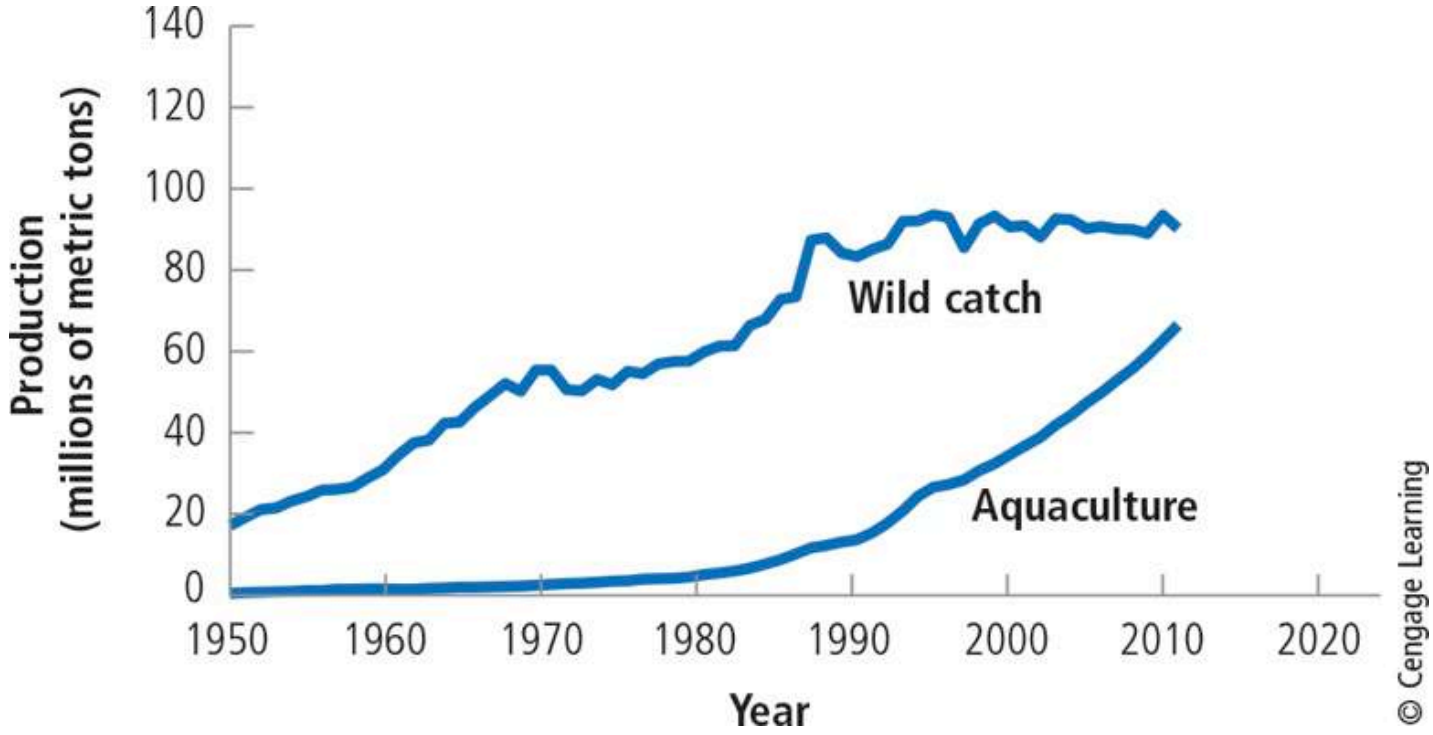
Fish and Shellfish Production Are Growing Rapidly (1 of 3)

- Fishery
  - Concentration of a particular species suitable for commercial harvesting
  - 30% are overfished
  - 57% harvested at full capacity

Fish and Shellfish Production Are Growing Rapidly (2 of 3)

- Aquaculture
  - Fish farming
  - Amount of fish and shellfish produced globally through aquaculture increased 12-fold from 1980 to 2014
    - Wild catch leveled off and declined
  - Farming of meat-eating species growing rapidly
    - Fed fish meal or fish oil produced from other fish

Fish and Shellfish Production Are Growing Rapidly (3 of 3)



Industrialized Food Production Requires Huge Inputs of Energy

- Mostly nonrenewable energy
  - Oil and natural gas
- 10 units of fossil fuel energy used for every unit of food energy in the U.S.
  - Amount of energy per calorie used in the U.S. has declined 50% since the 1970s
    - Less energy required to produce nitrogen fertilizer
    - Rising use of conservation tillage

12.3 What Are the Environmental Effects of Industrialized Food Production?

- Factors that may limit future food production
  - Soil erosion and degradation
  - Desertification
  - Irrigation water shortages
  - Air and water pollution
  - Climate change
  - Loss of biodiversity

Producing Food Has Major Environmental Impacts (1 of 2)

- Industrialized agriculture has harmful environmental impacts
  - Uses about 70% of freshwater removed from aquifers and surface waters worldwide
  - Emits 25% of the world's greenhouse gas emissions
  - Produces 60% of all water pollution

Producing Food Has Major Environmental Impacts (2 of 2)

Natural Capital Degradation

Food Production

Biodiversity Loss

Conversion of grasslands, forests, and wetlands to crops or rangeland

Fish kills from pesticide runoff

Killing of wild predators to protect livestock

Loss of agrobiodiversity replaced by monoculture strains

Soil

Erosion

Loss of fertility

Salinization

Waterlogging

Desertification

Water

Aquifer depletion

Increased runoff, sediment pollution, and flooding from cleared land

Pollution from pesticides

Algal blooms and fish kills caused by runoff of fertilizers and farm wastes

Air Pollution

Emissions of greenhouse gases CO_2 from fossil fuel use, N_2O from inorganic fertilizer use, and methane (CH_4) from cattle

Other air pollutants from fossil fuel use and pesticide sprays

Human Health

Nitrates in drinking water (blue baby)

Pesticide residues in water, food, and air

Livestock wastes in drinking and swimming water

Bacterial contamination of meat

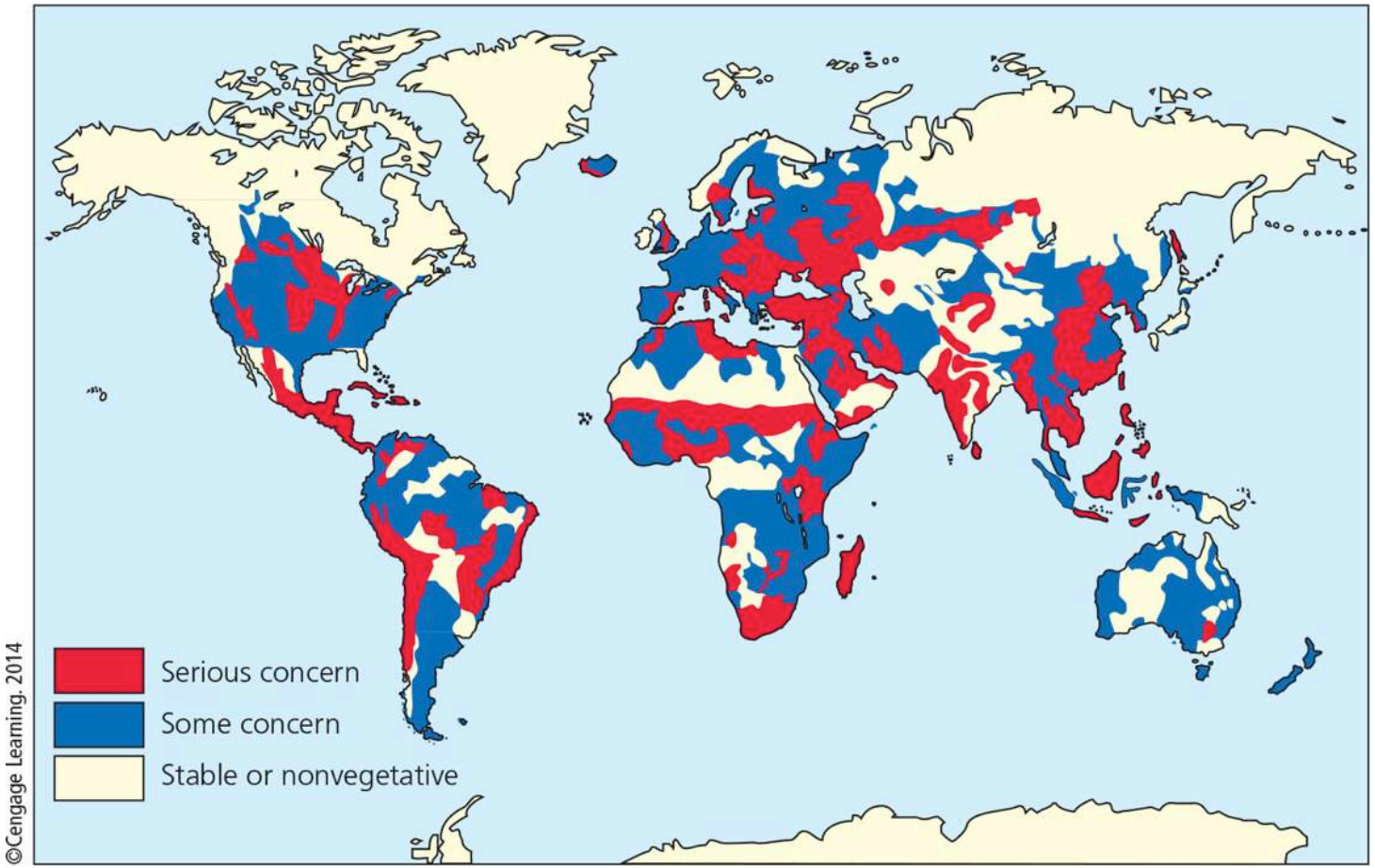
Topsoil Erosion Is a Serious Problem (1 of 3)

- Soil erosion
  - Movement of soil by wind and water
  - Natural causes
  - Human causes
- Three major harmful effects of soil erosion
  - Loss of soil fertility
  - Water pollution
  - Release of carbon stored in the soil as CO_2

Topsoil Erosion Is a Serious Problem (2 of 3)

Lynn Betts/USDA Natural Resources Conservation Service

Topsoil Erosion Is a Serious Problem (3 of 3)



Stepped Art

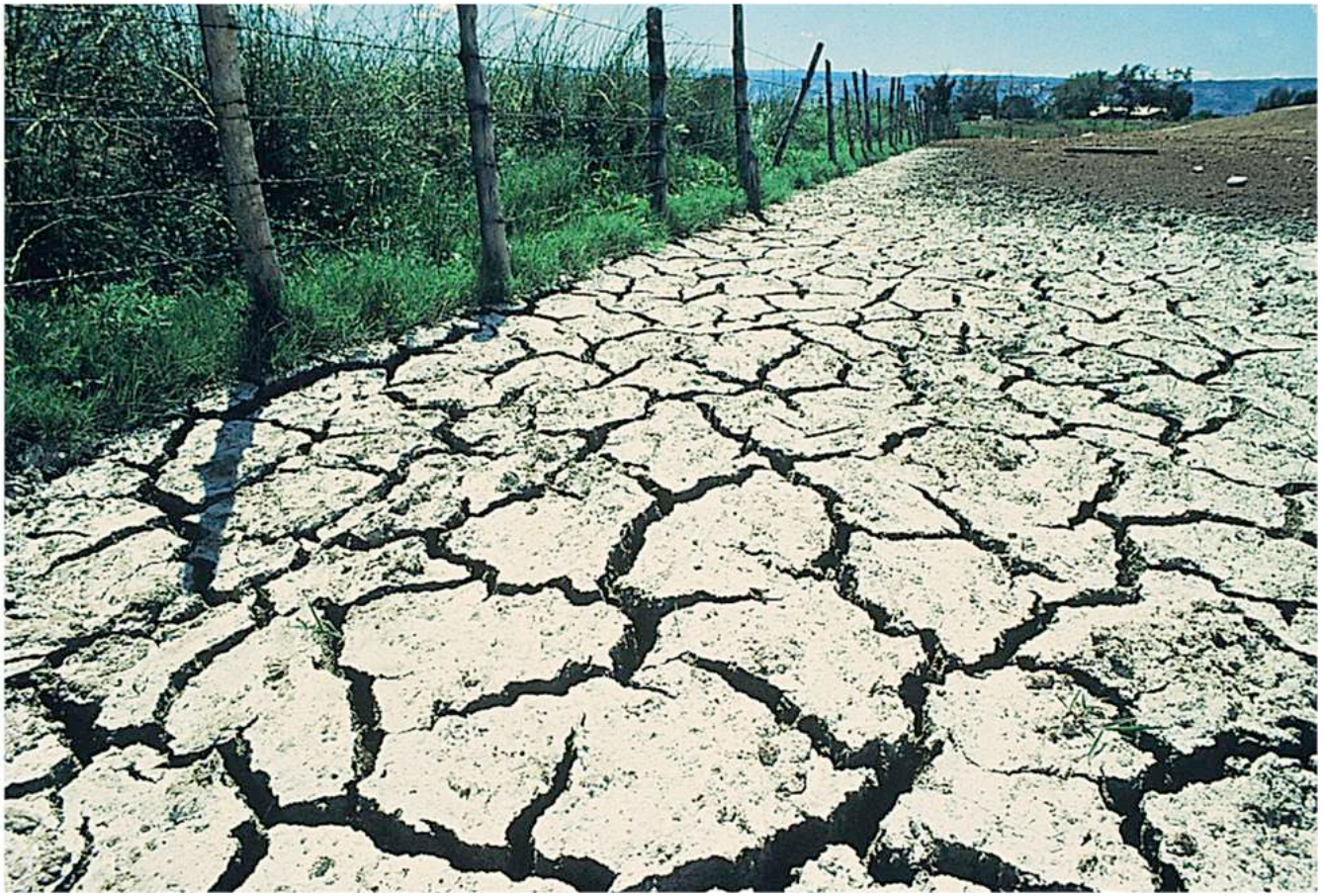
Drought and Human Activities Are Degrading Drylands

- Desertification
  - Productive potential of topsoil falls by 10% or more
  - Caused by prolonged drought and human activities
- Human agriculture accelerates desertification
- Dust bowl
  - Severe wind erosion of topsoil

Excessive Irrigation Can Pollute Soil and Water (1 of 2)

- Soil salinization
  - Gradual accumulation of salts in the soil from irrigation water
  - Lowers crop yields and eventually kills plants
  - Affects 10% of world croplands
- Waterlogging
  - Irrigation water gradually raises water table
  - Can deprive plants of oxygen
  - Affects 10% of world croplands

Excessive Irrigation Can Pollute Soil and Water (2 of 2)



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Industrialized Crop Production Contributes to Pollution and Climate Change

- Eroded topsoil flows into streams
  - Aquatic organisms ingest pesticide residues
- Farmers contribute to pollution through overfertilizing
  - Nitrates contaminate groundwater used for drinking
- Agricultural activities comprise more than 25% of human-generated CO_2 emissions

Producing Food and Biofuel Reduces Biodiversity

- Biodiversity threatened when forest and grasslands replaced with croplands
- Agrobiodiversity
  - Genetic variety of animal and plant species used on farms to produce food
  - 75% lost since 1900
- Efforts to save endangered crop varieties
  - Refrigerated seed banks

There Is Controversy over Genetically Engineered Foods (1 of 2)

- Genetic engineering could help improve food security
- Little is known about long-term health effects
  - Bt toxins could trigger inflammatory response
- Potential environmental effects of genetically modified populations in the wild
  - Creating hybrids with natural organisms

There Is Controversy over Genetically Engineered Foods (2 of 2)

Trade-Offs

Genetically Modified Crops and Foods

Potential Benefits	Possible Drawbacks
May need less fertilizer, pesticides, and water	Have unpredictable genetic and ecological effects
Can be resistant to insects, disease, frost, and drought	May put toxins in food
Can grow faster and could raise yields	Could repel or harm pollinators
May tolerate higher levels of herbicides	Can promote pesticide-resistant insects, herbicide-resistant weeds, and plant diseases
Could have longer shelf life	Could disrupt seed market and reduce biodiversity

There Are Limits to Expanding Green Revolutions

- Most green revolution and GE crop varieties:
  - Require large inputs of fertilizer, pesticides, and water
    - Often too expensive for many farmers
  - Produce yields no higher than those of traditional strains

Organic Farming Has Some Drawbacks

- Potential problem
  - Leaching nitrates into groundwater from composted manure used as fertilizer
  - Large-scale composting generates greenhouse gases
  - Some organic farmers resort to plowing to control weeds
    - Leads to soil erosion and loss of soil nutrients
    - Organic no-till system has been developed

Industrialized Meat Production Harms the Environment (1 of 2)

- Pros:
  - Increased meat supply
  - Reduced overgrazing
  - Kept food prices down
- Cons:
  - Uses large amounts of water to irrigate grain crops fed to animals
  - Livestock wastes pollute waterways
  - Uses large amounts of energy

Industrialized Meat Production Harms the Environment (2 of 2)

Trade-Offs

Feedlots and CAFOs

Advantages	Disadvantages
Increased meat production	Animals unnaturally confined and crowded
Higher profits	Large inputs of grain, fishmeal, water, and fossil fuels
Less land use	Greenhouse gas (CO_2 and CH_4) emissions
Reduced overgrazing	Concentration of animal wastes that can pollute water
Reduced soil erosion	Use of antibiotics can increase genetic resistance to microbes in humans
Protection of biodiversity	

Aquaculture Can Harm Aquatic Ecosystems (1 of 2)

- Several environmental problems
  - Fish are caught to use as feed on fish farms
    - Contributes to depletion of wild wish
    - Environmental toxins
  - Pesticides and antibiotics on fish farms a source of pollution
  - Can destroy or degrade mangrove forests

Aquaculture Can Harm Aquatic Ecosystems (2 of 2)

Trade-Offs

Aquaculture

Advantages		Disadvantages
High efficiency		Large inputs of land, grain, and fishmeal
High yield		Large waste output
Reduces over-harvesting of fisheries		Loss of mangrove forests and estuaries
Jobs and profits		Dense populations vulnerable to disease

12.4 How Can We Protect Crops from Pests More Sustainably?

- We can sharply cut pesticide use without decreasing crop yields by using a mix of:
  - Cultivation techniques
  - Biological pest controls
  - Small amounts of selected chemical pesticides as a last resort (integrated pest management)

Nature Controls the Populations of Most Pests

- Pests
  - Interfere with human welfare
- Natural enemies control pest populations
  - Predators, parasites, disease organisms
  - In natural ecosystems
  - Free ecosystem service

Synthetic Pesticides Can Help Control Pest Populations (1 of 2)

- Synthetic pesticides
  - Chemicals used to kill or control pests
  - Include insecticides, herbicides, fungicides, and rodenticides
- Biopesticides
  - Produced by plants to ward off insects and herbivores

Synthetic Pesticides Can Help Control Pest Populations (2 of 2)

- First-generation pesticides
  - Borrowed from plants
- Second-generation pesticides: DDT
  - Lab produced
- Broad-spectrum agents
  - Can be toxic to beneficial species
- Narrow-spectrum agents
- Persistence varies

Benefits of Synthetic Pesticides

- Human lives saved from malaria
- Increase food supplies and reduce food losses
- Help control erosion and build soil fertility
  - By avoiding plowing
- Help farmers reduce costs
- Newer pest control methods are safer and more effective

Problems with Synthetic Pesticides (1 of 4)

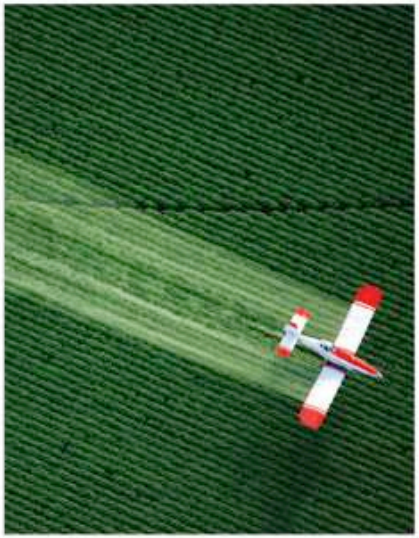
- Accelerate development of genetic resistance in pests
- Expensive for farmers
- Some insecticides kill natural predators or parasites that help control pests
- Cause environmental pollution
- Some harm wildlife
- Some are human health hazards

Problems with Synthetic Pesticides (2 of 4)

Trade-Offs

Synthetic Pesticides

Advantages	Disadvantages
Expand food supplies	Promote genetic resistance
Raise profits	Can kill pests' natural enemies and harm wildlife and people
Work fast	Can pollute air, water, and land
Are safe if used properly	Are expensive for farmers



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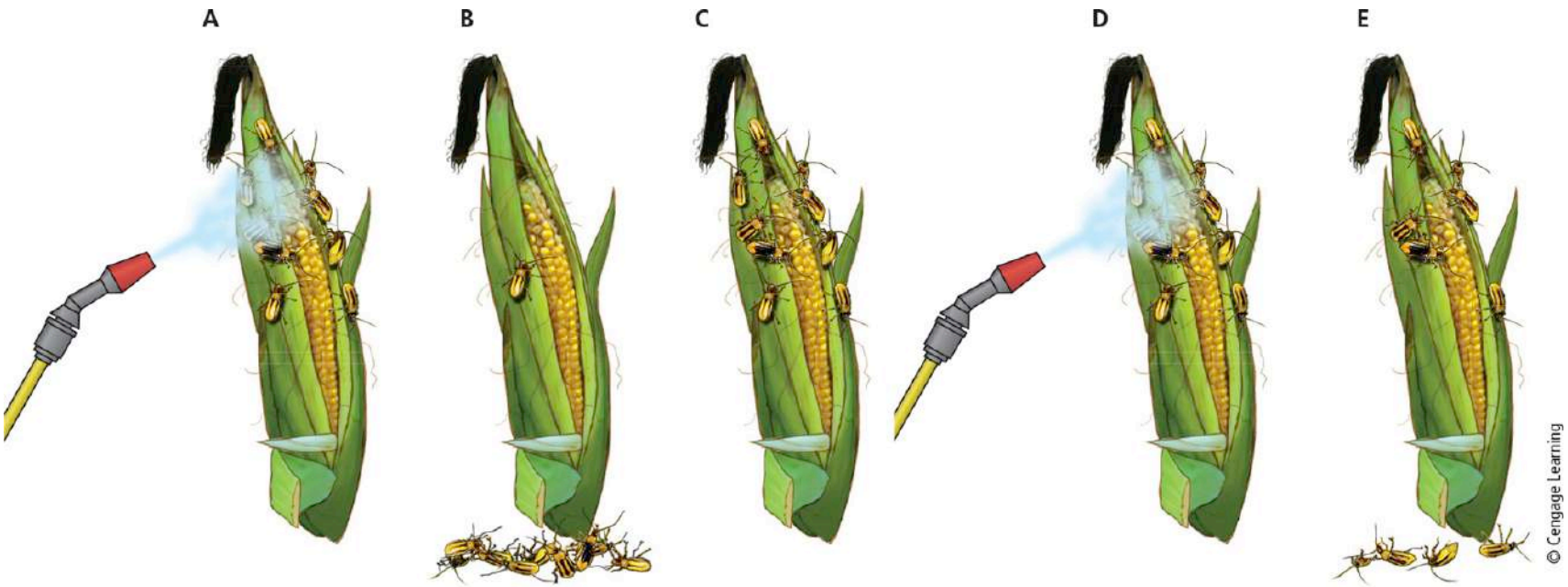
Problems with Synthetic Pesticides (3 of 4)



Problems with Synthetic Pesticides (4 of 4)

- What Can You Do?
  - Reducing Exposure to Pesticides
    - Grow some of your food using organic methods
    - Buy certified organic food
    - Wash and scrub all fresh fruits and vegetables
    - Eat less meat, no meat, or certified organically produced meat
    - Before cooking, trim the fat from meat

Pesticide Use Has Not Consistently Reduced U.S. Crop Losses to Pests

- 1942-1997–crop losses from insects increased from 7% to 13%, even with 10x increase in pesticide use
- 2014 study: no increase in soybean crop yields for crops treated with three controversial neonicotinoids
  - Pesticide industry disputes findings

Laws and Treaties Can Help to Protect Us from the Harmful Effects of Pesticides

- U.S. federal agencies and laws
  - EPA, USDA, FDA
  - Fungicide and Rodenticide Act, 1947
  - Food Quality Protection Act, 1996
- Federal laws regulating pesticide use inadequate and poorly enforced
- The U.S. exports many banned pesticides
  - Poisons can be transmitted in the atmosphere

There Are Alternatives to Synthetic Pesticides

- Biological controls
  - Natural predators and parasites
  - Pheromones and hormones
- Ecological controls
  - Use plant diversity to provide habitats for predators of pest species
- Cultivation controls
  - Vary crops and adjust planting times

IPM Is a Component of More Sustainable Agriculture

- Integrated pest management (IPM)
  - Program in which each crop and its pests are evaluated as parts of an ecosystem
  - Goal: minimal use of synthetic pesticides
- Disadvantages
  - Requires expert knowledge
  - Methods applied in one area might not apply in another
  - Initial costs higher

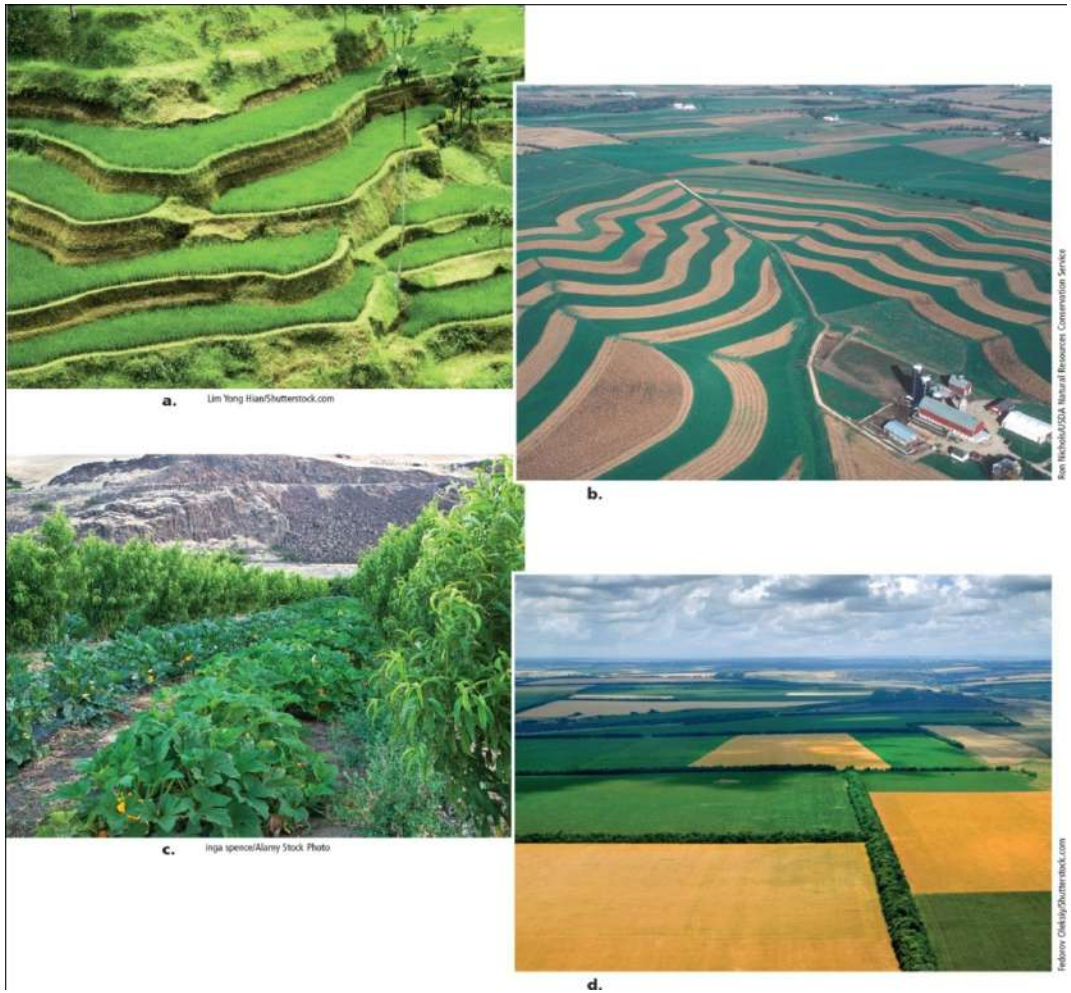
12.5 How Can We Produce Food More Sustainably?

- We can produce food more sustainably by:
  - Using resources more efficiently
  - Sharply decreasing the harmful environmental effects of industrialized food production
  - Eliminating government subsidies that promote such harmful impacts

Conserve Topsoil (1 of 2)

- Soil conservation
  - Terracing
  - Contour planting
  - Strip cropping with cover crop
  - Alley cropping, agroforestry
  - Windbreaks or shelterbelts
  - Conservation-tillage farming
- Identify erosion hotspots

Conserve Topsoil (2 of 2)



Restore Soil Fertility

- Organic fertilizer
  - Animal manure
  - Green manure
  - Compost
- Manufactured inorganic fertilizer
  - Nitrogen, phosphorus, and potassium
- Biochar
- Crop rotation

Reduce Soil Salinization and Desertification (1 of 2)

- Soil salinization
  - Costly solutions
- Desertification
  - Reduce:
    - Population growth
    - Overgrazing
    - Deforestation
    - Destructive forms of planting, irrigation, and mining
  - Plant trees that anchor topsoil

Reduce Soil Salinization and Desertification (2 of 2)

Solutions

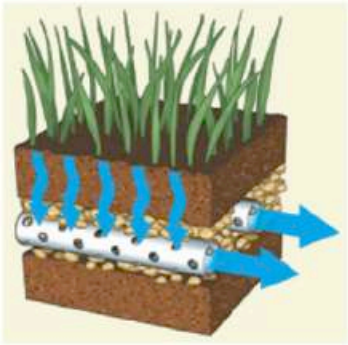
Soil Salinization

Prevention

Reduce irrigation

Use more efficient irrigation methods

Switch to salt-tolerant crops



Cleanup

Flush soil (expensive and inefficient)

Stop growing crops for 2–5 years

Install underground drainage systems

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Produce and Consume Meat and Dairy Products More Sustainably (1 of 2)

- Shift from less-efficient forms of animal protein to more efficient
  - Pork and poultry are more efficient than beef
- Reduce or eliminate meat intake
- Insects another source of protein
- India's dairy industry uses crop residues such as rice straw and corn stalks
  - Saves energy and reduces greenhouse gas emissions

Produce and Consume Meat and Dairy Products More Sustainably (2 of 2)

Practice More Sustainable Aquaculture (1 of 2)

- Aquaculture stewardship council
  - Developed sustainability standards
  - Certified 4.6% of world's aquaculture operations
- Open-ocean aquaculture
- Recirculating aquaculture
  - Water is continually recycled
- Polyaquaculture

Practice More Sustainable Aquaculture (2 of 2)

- Solution
  - More Sustainable Aquaculture
    - Protect mangrove forests and estuaries
    - Improve management of wastes
    - Reduce escape of aquaculture species into the wild
    - Set up self-sustaining polyaquaculture systems that combine aquatic plants, fish, and shellfish
    - Certify sustainable forms of aquaculture

Expand Organic Agriculture

- Some benefits of organic farming
  - Builds soil organic matter
  - Reduces erosion and water pollution
  - Uses less fossil fuel energy
  - Cuts greenhouse gas emissions
  - Match conventional yields
  - More weed-tolerant
  - Crops compare favorably in years of drought
  - More profitable

Shift to More Sustainable Food Production (1 of 3)

- Components of sustainable agriculture
  - Rely more on organic polyculture
    - Less on conventional monoculture
  - Grow perennial crops
  - Rely more on renewable energy
  - Tailor fertilizers to different soil conditions to minimize runoff
  - Irrigate more efficiently

Shift to More Sustainable Food Production (2 of 3)

Solutions

More Sustainable Food Production

More	Less
High-yield polyculture	Soil erosion
Organic fertilizers	Soil salinization
Biological pest control	Water pollution
Integrated pest management	Aquifer depletion
Efficient irrigation	Overgrazing
Perennial crops	Overfishing
Crop rotation	Loss of biodiversity and agrobiodiversity
Water-efficient crops	Fossil fuel use
Soil conservation	Greenhouse gas emissions
Subsidies for sustainable farming	Subsidies for unsustainable farming

Shift to More Sustainable Food Production (3 of 3)

- What Can You Do?
  - More Sustainable Food Production
    - Eat less meat, no meat or organically certified meat
    - Choose sustainably produced herbivorous fish
    - Use organic farming to grow some of your food
    - Buy certified organic food
    - Eat locally grown food
    - Compost food wastes
    - Cut food waste

12.6 How Can We Improve Food Security?

- Government policies have controlled food prices and provided subsidies
  - New Zealand and Brazil have ended farm subsidies successfully
- Government and private programs that target poverty can improve food security
  - Low-interest loans
  - Immunizations and vitamins for children

We Can Grow and Buy More Food Locally and Cut Food Waste (1 of 4)

- Community supported agriculture
  - People buy a share of a local farmer's crops
  - Receive box of produce on a regular basis during growing season
  - Supports local economies and farm families
- Much food waste occurs in restaurants, homes, and supermarkets
  - 30–40% of food supply thrown away each year

We Can Grow and Buy More Food Locally and Cut Food Waste (2 of 4)

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We Can Grow and Buy More Food Locally and Cut Food Waste (3 of 4)

- Trade-Offs
- Challenges
  - Demand Side
    - Growing population
    - People moving up the food Chain
    - Turning food into biofuel
  - Supply Sides
    - Soil erosion
    - Depletion of aquifers
    - Stagnant grain yields
    - Rising temperature

We Can Grow and Buy More Food Locally and Cut Food Waste (4 of 4)

- Solutions
  - Demand Side
    - Stabilize population
    - Eradicate poverty
    - Reduce excessive meat consumption
    - Eliminate biofuel subsidies
  - Supply Sides
    - Conserve soil
    - Use water efficiently
    - Find ways to increase yields
    - Stabilize climate

Big Ideas (1 of 2)

- About 795 million people have health problems because they do not get enough to eat
  - 2.1 billion people face health problems from eating too much
- Modern industrialized agriculture has a greater harmful impact on the environment than any other human activity

Big Ideas (2 of 2)

- More sustainable forms of food production
  - Greatly reduce harmful environmental impacts of industrialized food production systems

Tying It All Together: Growing Power and Sustainability

- Transition to more sustainable food production
  - Rely more on solar energy
  - Conserve topsoil
  - Return crop residues and animal wastes to the soil
  - Rely on a greater variety of crop and animal strains
  - Use polyculture and IPM to control pests