

# Environmental Science, 15e

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## 10

### Food Production and the Environment

# Core Case Study: Growing Power -- An Urban Food Oasis

- Growing Power Inc.
  - An ecologically based farm powered by solar electricity and hot water systems that grows organic vegetables and herbs – and organically raised chickens, turkeys, goats, fish, and honeybees
- How does this farm use the principles of sustainability?

## 10.1 What Is Food Security and Why Is It Difficult To Attain?

- In less developed countries, people suffer from health problems associated with not getting enough to eat
- In more developed countries, others suffer health problems from having too much to eat
- Factors influencing food supply: poverty, war, bad weather, climate change, and effects of industrialized food production

# Poverty Is the Root Cause of Food Insecurity

- Scientists project that by 2050, we will need to feed at least 9.7 billion people, almost half of which live in poverty and experience food insecurity
  - How do we feed more people without seriously harming the environment?
- Many people suffer from chronic hunger and malnutrition and don't get enough vitamins and minerals

# Malnutrition

- Low income, less developed countries: diets center on high carbohydrate grains and very little protein
- Food deserts (no access to fresh food) in developed countries: diets high in fat, sugar, salt, and little protein
- Almost 2 billion people suffer from a deficiency of micronutrients (vitamin A, iron, and iodine)

## 10.2 How Is Food Produced?

- Today, agriculture uses both high input industrialized, and low input traditional methods, to produce the world's food supply

# Industrialized and Traditional Crop Production

- Industrialized/high input agriculture: heavy equipment, fossil fuel, commercial fertilizer/pesticides, and money (monoculture: growing one to two crops)
  - Food supply vulnerable to disease
- Traditional/low input agriculture: solar energy and human labor to grow a crop that will feed a family with no surplus (polyculture: growing several crops)



# Differences Between Industrialized and Organic Agriculture

## Industrialized Agriculture



Uses synthetic inorganic fertilizers and sewage sludge to supply plant nutrients

Makes use of synthetic chemical pesticides



Uses conventional and genetically modified seeds

Depends on nonrenewable fossil fuels (mostly oil and natural gas)



Produces significant air and water pollution and greenhouse gases

Is globally export-oriented

Uses antibiotics and growth hormones to produce meat and meat products

## Organic Agriculture



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

Employs crop rotation and biological pest control



Uses no genetically modified seeds

Reduces fossil fuel use and increases use of renewable energy such as solar and wind power for generating electricity



Produces less air and water pollution and greenhouse gases

Is regionally and locally oriented

Uses no antibiotics or growth hormones to produce meat and meat products

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# Organic Agriculture and the Green Revolution

- Organic agriculture: crops grown without the use of synthetic pesticides and inorganic fertilizers, or genetic engineering
- Green revolution: higher yields from existing cropland
  - Plant monocultures of selectively bred crops
  - Large amounts of water; synthetic fertilizers and pesticides
  - Multiple cropping

# Food Demands, Consumption, and Rising Industrialized Productivity

- The increasing demand for food is being met by increases in production
  - New and hardier crop varieties are being developed by second gene revolution methodology (gene splicing)
  - Meat production now uses feedlots as well as rangelands and pastures
  - Aquaculture produces more fish and is the world's fastest growing type of food production

# Industrialized Food Production Requires Huge Inputs of Energy

- Large inputs of energy are needed to grow, store, process, package, transport, refrigerate, and cook plants and animals
  - In the U.S., 10 units of fossil fuel energy are needed to produce 1 unit of food energy
  - Fishing fleets use 12.5 units of energy to produce 1 unit of energy from seafood
  - Industrialized food production is dependent on fossil fuel, resulting in a net energy loss

## 10.3 What Environmental Problems Arise from Industrialized Food Production?

- Soil erosion, desertification, irrigation, water shortages, air and water pollution, climate change and loss of biodiversity may limit future food production

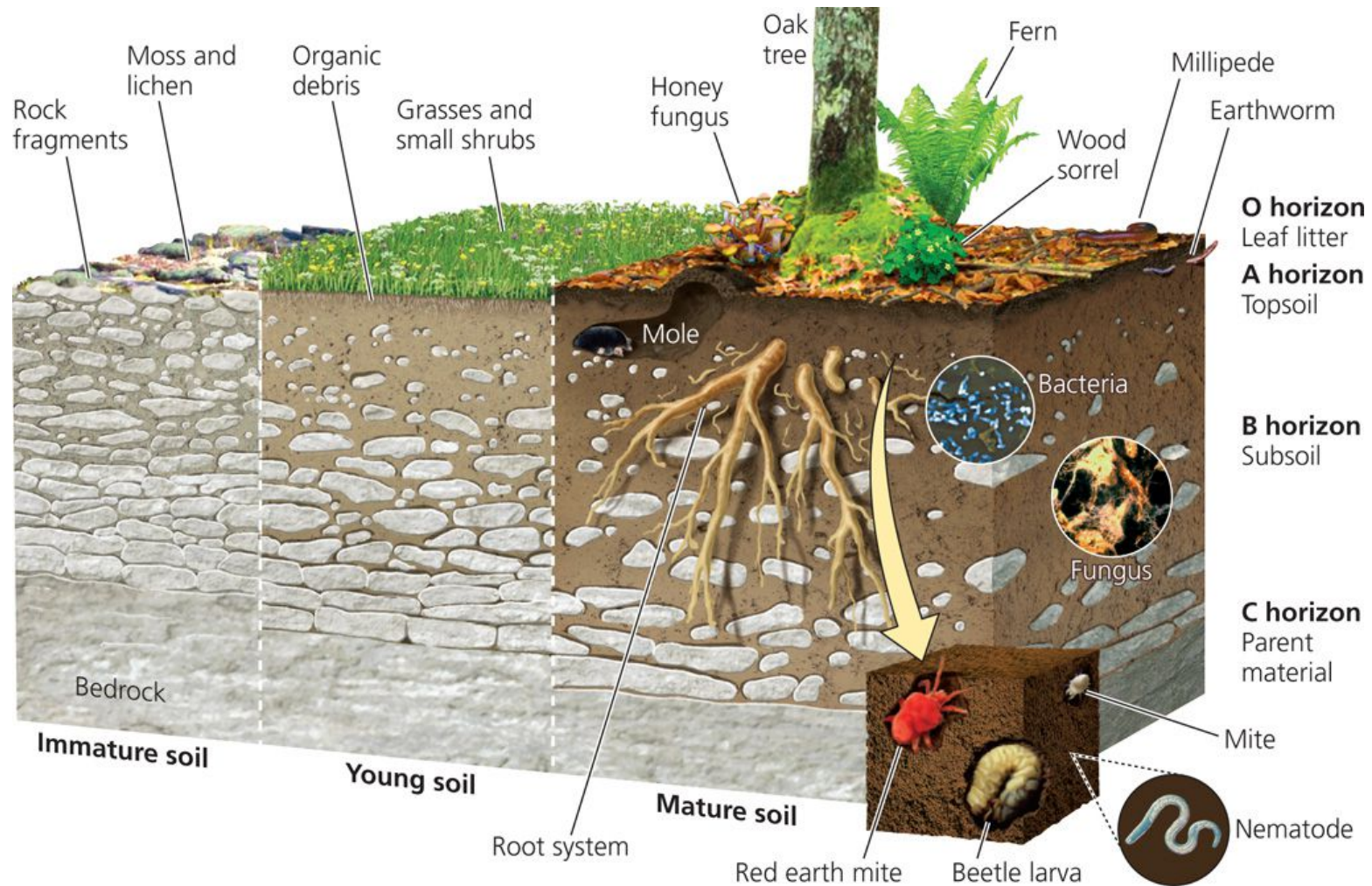
# Producing Food Has Major Environmental Impacts

- While industrialized agriculture has allowed farmers to use less land to produce more food, it is environmentally and economically unsustainable
  - Industrialized agriculture:
    - Removes 70% of fresh water from surface sources and aquifers
    - Uses 38% of the world's ice-free land
    - Emits 25% of all greenhouse gas emissions
    - Produces 60% of all water pollution

# Topsoil Erosion Is a Serious Problem in Parts of the World

- Topsoil (the fertile top layer of many soils), is a significant natural capital component because it stores water and nutrients needed by plants
- Topsoil renewal is one of the earth's most important ecosystem services
  - Topsoil nutrients recycle endlessly as long as they are not removed faster than natural processes replace them

# Generalized Soil Profile



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# Soil Erosion

- The movement of soil from one place to another by nature and by human activity
  - Flowing water (the largest cause of soil erosion) carries away soil loosened by rainfall
  - Wind loosens and blows away topsoil particles – from flat land in dry climates
  - Farming, deforestation, and overgrazing exposes land and hastens soil erosion

# Harmful Affects of Soil Erosion

- Loss of soil fertility through the depletion of plant nutrients in topsoil
- Topsoil pollution of surface waters can kill fish and clog reservoirs and lakes
  - Increased if it contains pesticide residues – biomagnified through food webs
- Erosion releases the soil's carbon content, which alters the carbon cycle, adding to atmospheric levels of CO<sub>2</sub>

# Natural Capital Degradation: Topsoil Erosion



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# Agricultural Activities Have Serious Environmental Consequences

- Irrigation boosts/lowers farm productivity
  - 20% of the world's irrigated crop land produces about 40% of the world's food
  - Irrigation water has a variety of salts, which leads to soil salinization
- Livestock production generates 18% of all greenhouse gas
- Fertilizer use releases nitrous oxide, increasing atmospheric temperatures



# Harmful Environmental Effects of Food Production

## 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<sub>2</sub> from fossil fuel use, N<sub>2</sub>O from inorganic fertilizer use, and methane (CH<sub>4</sub>) 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

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# Biodiversity Loss During Food Production

- Clearing and burning forests leads to the loss of natural biodiversity
- Deforestation in the Amazon Basin and clearing of grasslands for cattle ranching and plantation farming (sugar cane) decreases biodiversity
  - As fewer varieties of plant and animal species are used in farming, agrobiodiversity decreases

# Are There Limits To the Expansion of the Green Revolutions?

- Genetically modified (GM) food production is controversial, with benefits/drawbacks
- Genetically engineered crop yields seem to be no higher than for traditional strains
- Population growth, water availability, and climate change limit irrigation's potential
- Deforestation speeds up climate change, increases topsoil erosion, and lowers biodiversity



# Tradeoffs of GM Crops and Foods

## Trade-Offs

### Genetically Modified Crops and Foods

#### Projected Advantages

May need less fertilizer, pesticides, and water

Can be resistant to insects, disease, frost, and drought

Can grow faster

May tolerate higher levels of herbicides



#### Projected Disadvantages

Have unpredictable genetic and ecological effects

May put toxins in food

Can promote pesticide-resistant insects, herbicide-resistant weeds, and plant diseases

Could disrupt seed market and reduce biodiversity

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# Harmful Environmental Effects of Industrialized Meat Production/Aquaculture

- Cheap meat produced by industrialized agriculture has harmful environmental and health costs not included in pricing – violating full-cost principle of sustainability
- Fishmeal and fish oil, food sources for farmed fish (often contaminated with toxins), come from wild fish caught from the oceans – biomagnified in human food web; depletes wild fish populations

# Tradeoffs: Animal Feedlots and Aquaculture

## Trade-Offs

### Animal Feedlots and CAFOs

#### Advantages

Increased meat production

Higher profits

Less land use

Reduced overgrazing

Reduced soil erosion

Protection of biodiversity



#### Disadvantages

Animals unnaturally confined and crowded

Large inputs of grain, fishmeal, water, and fossil fuels

Greenhouse gas (CO<sub>2</sub> and CH<sub>4</sub>) emissions

Concentration of animal wastes that can pollute water

Use of antibiotics can increase genetic resistance to microbes in humans

## Trade-Offs

### Aquaculture

#### Advantages

High efficiency

High yield

Reduces over-harvesting of fisheries

Jobs and profits



#### Disadvantages

Use of fish oil and fishmeal on fish farms depletes wild fisheries

Large waste output

Loss of mangrove forests and estuaries

Dense populations vulnerable to disease

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## 10.4 How Can We Protect Crops from Pests More Sustainably?

- Using a mix of cultivation techniques, biological pest controls, and selective chemical pesticides (as a last resort) will enable farmers to sharply decrease pesticide use without decreasing crop yields

# Nature Controls the Populations of Most Pests

- Natural enemies control the populations of most pest species
  - This free ecosystem service is an important part of earth's natural capital
- Humans upset the checks and balances of natural pest control when we clear forests and grasslands, plant monoculture crops, and use synthetic chemicals to kill pests

# Advantages of Synthetic Pesticide Use

- Human lives have been saved from insect transmitted disease (especially malaria)
- Food supplies are increased by reducing food loss due to pests
- Crop yields and farming profits increase
- Newer pesticides are safer, more effective, and work faster – and when properly used, keep health risks very low relative to benefits

# Disadvantages of Synthetic Pesticide Use

- The genetic development of pesticide resistance in pest organisms
- Long term usage diminishes effectiveness – costing farmers more for less return
- Insecticides kill the pest's natural enemies
- Inefficient application causes pollution
- Both wildlife and human health are affected



# Tradeoffs of Conventional Chemical Pesticides

## Trade-Offs

### Conventional Chemical Pesticides

#### Advantages

Expand food supplies

Raise profits

Work fast

Are safe if used properly



#### Disadvantages

Promote genetic resistance

Can kill pests' natural enemies and harm wildlife and people

Can pollute air, water, and land

Are expensive for farmers

# Protective Laws and Treaties

- Pesticide usage is regulated by:
  - Environmental Protection Agency (EPA), U.S. Department of Agriculture (USDA), and the Food and Drug Administration (FDA) under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)
- Unfortunately adequate funding has not been provided for effective management and enforcement of FIFRA

# Alternatives to Synthetic Pesticide Use

- Crop rotation/adjusting planting time starves pests/allows enemies to eat them
- Polyculture provides homes for pest's enemies
- Implant genetic resistance
- Biological control: use natural enemies
  - Natural pheromones (insect perfume)
    - Can lure pests into traps
    - Can attract natural enemies into crop fields

# More Alternatives to Synthetic Pesticide Usage

- Disrupt the life cycles of insects by altering their hormones
  - Using insect perfume and hormone alteration are both time consuming and costly
- Reduce synthetic herbicide usage to control weeds
- Integrated pest management (IPM) – use of a coordinated combination of cultivation, biological and chemical tools

## 10.5 How Can We Improve Food Security?

- Reducing poverty and malnutrition, producing food more sustainably, and relying on locally sourced food will improve food security

# The Government's Role in Improving Food Production and Security

- Controlling food prices vs. food subsidies
- Implementing health measures
- Aid local, sustainable, organic food production and distribution
- Educate farmers
- Encourage Community Supported Agriculture (CSA) programs and vertical farming

## 10.6 How Can We Produce Food More Sustainably?

- Efficient resource use, reducing the harmful effects of Industrialized food production, and eliminating government subsidies will help us produce food more sustainably



# Reducing Soil Erosion and Salinization, and Increasing Soil Fertility

- Soil conservation (terracing, contour planting, strip-cropping, planting cover crops, and setting up windbreaks)
- Alley cropping, agroforestry (planting crops in orchards) and tillage farming
- Organic fertilizer use (animal/green manure, compost) to restore soil fertility
- Reducing irrigation dependence; rotating crops/switching to salt tolerant varieties

# Sustainable Food Production Solutions

- Open-ocean/polyaquaculture
- Re-circulating aquaculture systems
- Eat more chicken and eat less grain-efficient species (beef, pork and lamb)
- Eat more locally sourced, organic food, and have two meatless meals per week
- Switch to organic farming, perennial polyculture, renewable energy usage, and subsidies for sustainable food production

# Solutions: More Sustainable Food Production

## Solutions

### More Sustainable Food Production

#### More

High-yield polyculture  
Organic fertilizers  
Biological pest control  
Integrated pest management  
Efficient irrigation  
Perennial crops  
Crop rotation  
Water-efficient crops  
Soil conservation  
Subsidies for sustainable farming



#### Less

Soil erosion  
Soil salinization  
Water pollution  
Aquifer depletion  
Overgrazing  
Overfishing  
Loss of biodiversity and agrobiodiversity  
Fossil fuel use  
Greenhouse gas emissions  
Subsidies for unsustainable farming

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# Additional Case Study: Vertical Farming

- Chicago is home to Farmed Here
  - Commercial vertical farming company that uses aquaponics (symbiotic cultivation of plants and aquatic animals) and aeroponics (hydroponically misting plant roots) to grow local produce year round.
  - Recycles 97% of the fresh water and use no herbicides or pesticides
  - Local company that delivers fish and vegetables only in the Chicago area

# More on Vertical Farming

- What is vertical farming?
- How do hydroponics, aquaponics, and aeroponics work?
- What makes the vertical farming idea using aquaponics so sustainable?
- Are vertically farmed foods available in your community? Would you buy and eat them?

# Vertical Farming and the Three Big Ideas

- The availability of healthy, fresh food helps eliminate both hunger and overeating
- Vertical farming has a beneficial impact on the environment – especially in formerly industrialized areas
- In the U.S., vertical farming can supply fresh food to urban food deserts at minimal cost – allowing people to have a healthier diet