

ESSENTIAL ENVIRONMENT

THE SCIENCE BEHIND THE STORIES



SECOND EDITION

7

Soil, Agriculture and the Future of Food

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This lecture will help you understand:

- Soil science fundamentals
- Soil erosion, degradation, and conservation
- The “green revolution”
- Pest management and pollination
- Genetically modified food
- Feedlots and aquaculture
- Sustainable agriculture



Central Case: No-Till Agriculture in Brazil



- Southern Brazil's farmers were suffering falling yields, erosion, and pollution from agrichemicals.
- They turned to no-till farming, which bypasses plowing.
- Erosion was reduced, soils were enhanced, and yields rose greatly. No-till methods are spreading worldwide.

Agriculture today

- We have converted 38% of Earth's surface for **agriculture**, the practice of cultivating soil, producing crops, and raising livestock for human use and consumption.
- **Croplands** (for growing plant crops) and **rangelands** (for grazing animal livestock) depend on healthy soil.

Traditional agriculture

...is agriculture by muscle power, animals, hand tools, and simple machines.

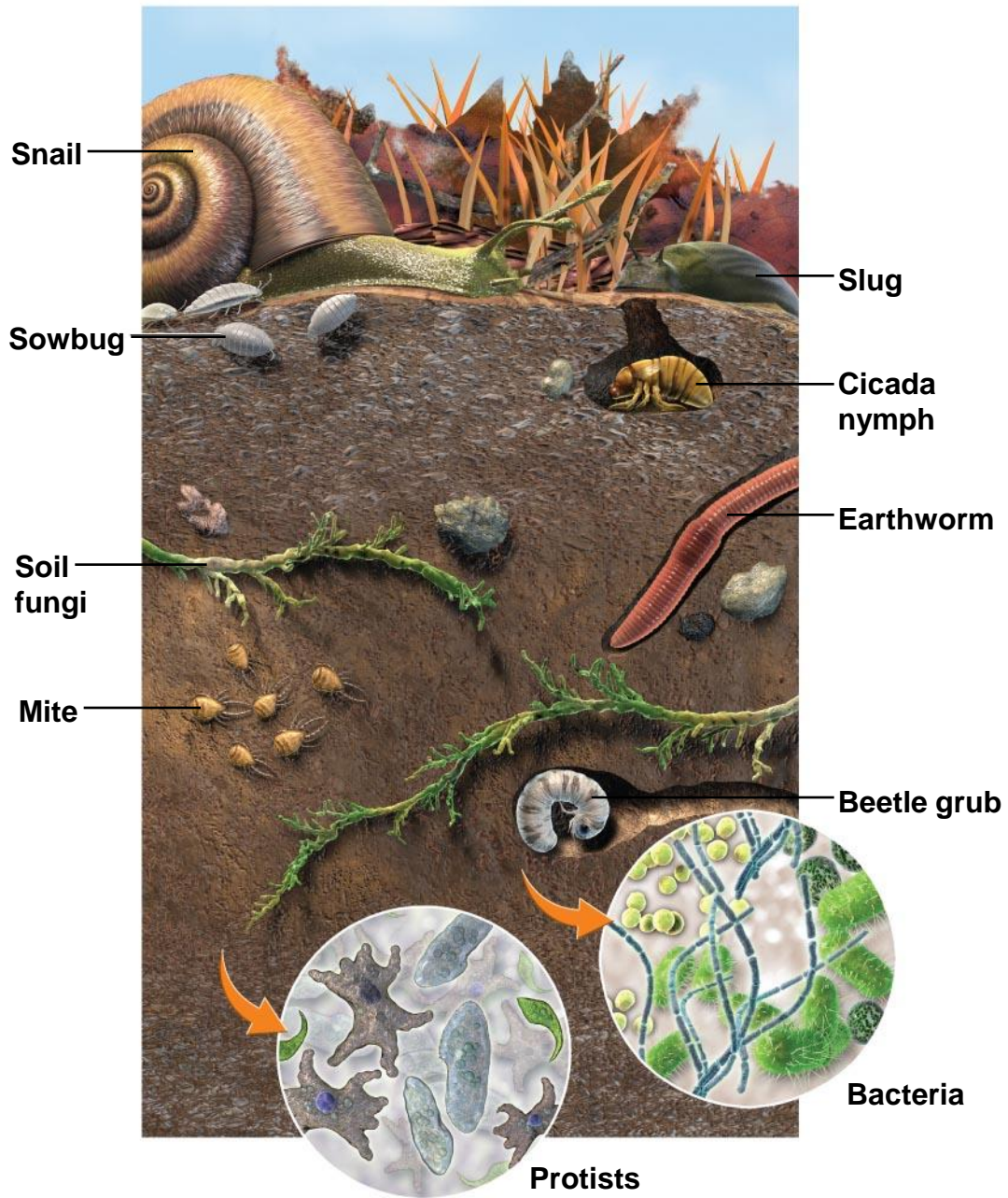
- **Subsistence agriculture** = family produces only enough for itself
- **Intensive traditional agriculture** = family uses animals, irrigation water, and fertilizer to produce enough to sell at market

Industrialized agriculture

- Industrialized agriculture can produce huge amounts of food efficiently.
- When managed improperly, industrialized agriculture can cause extensive environmental damage, including the destruction of fertile soil.

Soil as a system

Soil, full of life, is a complex mixture of organic and inorganic components.

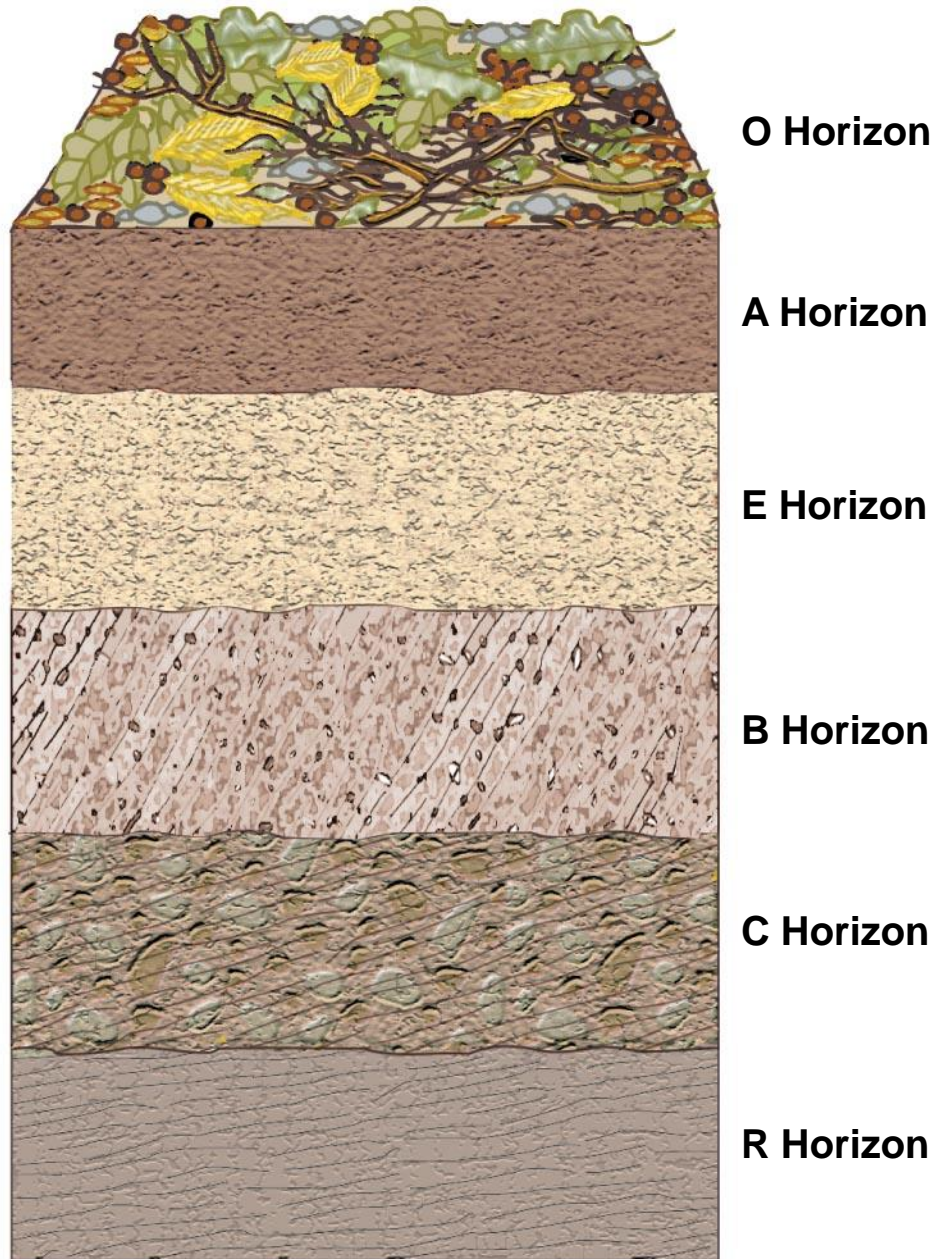


Soil formation

- **Parent material** = starting material that affects the composition of the resulting soil.
- Parent material can include **bedrock**, the solid rock that makes up the Earth's crust.
- **Weathering** = the processes that break down rocks and minerals, and the first step in soil formation.
- **Erosion** = the movement of soil from one area to another.

Soil profile

- Consists of layers called **horizons**
- *Simplest:*
 - A = topsoil*
 - B = subsoil*
 - C = parent material*
- But most have O, A, E, B, C, and R



Soil profile

- **O Horizon:** Organic or litter layer
- **A Horizon:** Topsoil; mostly inorganic minerals with some organic material and humus mixed in; crucial for plant growth
- **E Horizon:** Eluviation horizon; loss of minerals by **leaching**, a process whereby solid materials are dissolved and transported away
- **B Horizon:** Subsoil; zone of accumulation or deposition of leached minerals and organic acids from above
- **C Horizon:** Slightly altered parent material
- **R Horizon:** Bedrock

Soil characterization

Soil can be characterized by color and several other traits:

- Texture
- Structure
- pH

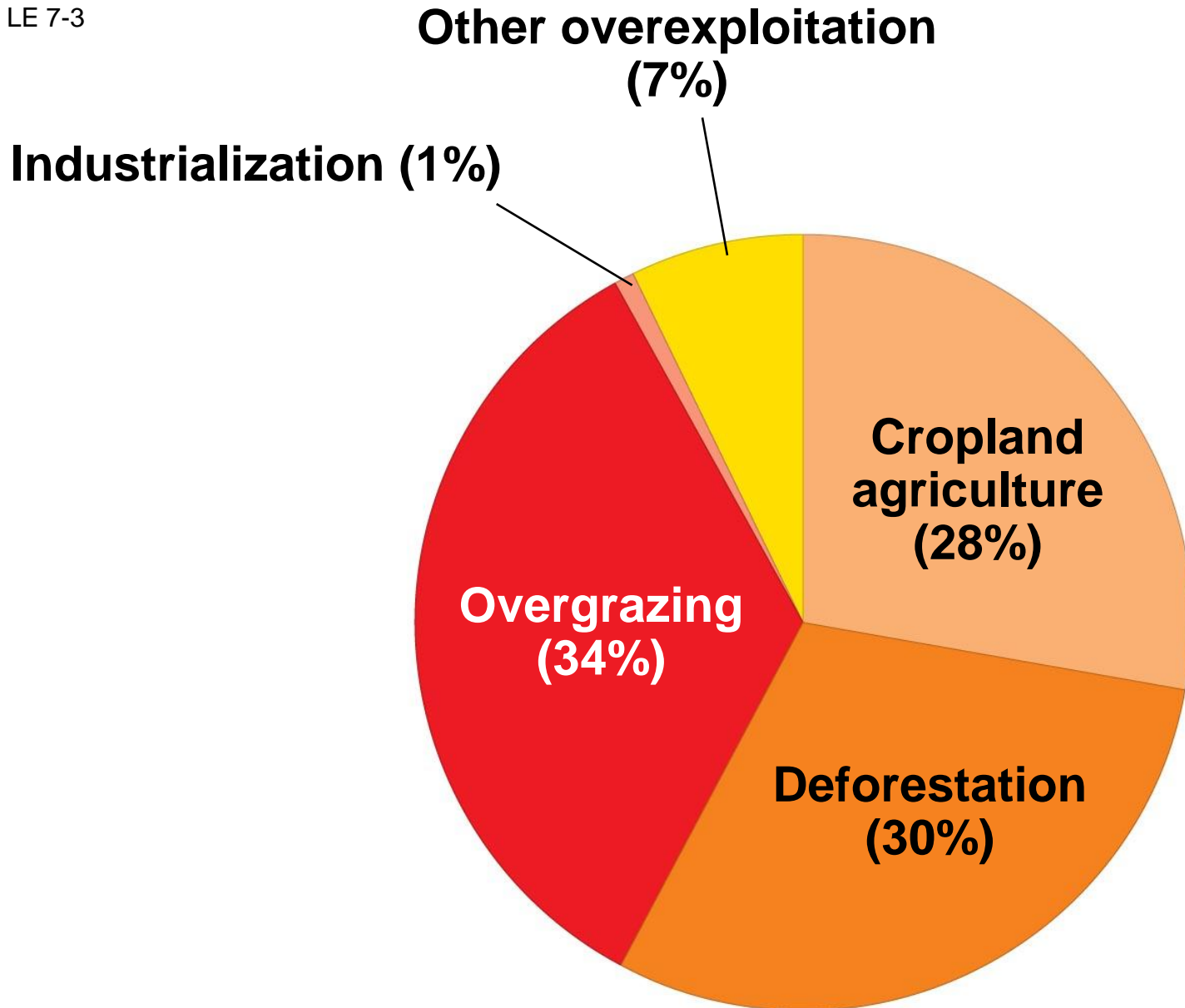
Soil with a relatively even mix of pore and particle sizes is **loam**. Loam with a pH close to neutral is the most desirable for agriculture.

Soil degradation

- Most of the world's soil is not ideal for agriculture.
- But population growth is pressing many unsuitable lands into farming, causing considerable soil damage.
- We are losing 5–7 million hectares (12–17 million acres) of productive cropland per year.
- This loss results from soil degradation, with erosion a key factor harming soil quality.

Key causes of soil degradation

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Erosion and deposition

- **Erosion** = removal of material from one place and its transport elsewhere
 - by wind
 - or water
- **Deposition** = arrival of eroded material at a new location
- These processes are natural and can build up fertile soil.
- But where artificially sped up, they are a big problem for farming.

Erosion

Commonly caused by:

- Overcultivating, too much plowing, poor planning
- Overgrazing rangeland with livestock
- Deforestation, especially on slopes

Soil erosion

- Soil erosion is a global problem.
- Coupled with rapid population growth, these two forces may spell crisis for the future of agriculture.
- Humans are the primary cause of erosion.
- People are over 10 times more influential at moving soil than are all other natural processes combined.

Desertification

A loss of more than 10% productivity due to:

- Erosion
- Soil compaction
- Forest removal
- Overgrazing
- Drought
- Salinization
- Climate change
- Depletion of water resources

When severe, desert areas may expand, or new ones may be created (e.g., the Middle East, formerly, “Fertile Crescent”).

The Dust Bowl



- Drought and degraded farmland produced the 1930s **Dust Bowl**.
- Storms brought dust from the U.S. Great Plains all the way to New York and Washington, and wrecked many lives.

Soil conservation

- As a result of the Dust Bowl,

the U.S. Soil Conservation Act of 1935 and

the Soil Conservation Service (SCS) were
created.
- **SCS:** Local agents in **conservation districts** worked with farmers to disseminate scientific knowledge and help them conserve their soil.

Soil conservation

Many nations followed the lead of the United States:

- Today local soil conservation agents help farmers in many places in the world.
- Brazil's no-till effort is based on local associations.

Preventing soil degradation

Several farming strategies to prevent soil degradation:

- Crop rotation
- Contour farming
- Intercropping
- Terracing
- Shelterbelts
- Conservation tillage (e.g., no-till)

Crop rotation

Alternating the crop planted (e.g., between corn and soybeans) can restore nutrients to soil and fight pests and disease.



(a) Crop rotation

Contour farming

Planting along contour lines of slopes helps reduce erosion on hillsides.



(b) Contour farming

Intercropping

Mixing crops such as in *strip cropping* can provide nutrients and reduce erosion.



(c) Intercropping

Terracing

Cutting stairsteps or terraces is the only way to farm extremely steep hillsides without causing massive erosion. It is labor-intensive to create but has been a mainstay for centuries in the Himalayas and the Andes.



(d) Terracing

Shelterbelts

Rows of fast-growing trees around crop plantings provide windbreaks, reducing erosion by wind.



(e) Shelterbelts

Conservation tillage

No-till and reduced-tillage farming leave old crop residue on the ground instead of plowing it into the soil. This covers the soil, keeping it in place.

Here, corn grows up out of a “cover crop.”



(f) No-till farming

No-till and reduced-tillage farming

Ending or reducing tillage has gained popularity but is not a panacea for all crops everywhere.

- It often requires more chemical herbicides (because weeds are not plowed under).
- It often requires more fertilizer (because other plants compete with crops for nutrients).

But legume cover crops can keep weeds at bay while nourishing soil, and green manures can be used as organic fertilizers.

Irrigation

...is the artificial provision of water to support agriculture.

- 70% of all freshwater used by people is used for irrigation.
- Irrigated land globally covers more area than all of Mexico and Central America combined.
- Irrigation has boosted productivity in many places ... but too much can cause problems.

Waterlogging and salinization

- Overirrigation can raise the water table high enough to suffocate plant roots with **waterlogging**.
- **Salinization** (buildup of salts in surface soil layers):
Evaporation in arid areas draws water up through the soil, bringing salts with it. Irrigation causes repeated evaporation, bringing more salts up.

Improved irrigation

- In **conventional irrigation**, only 43% of the water reaches plants.
- Efficient **drip irrigation** targeted to plants conserves water.



(a) Conventional irrigation



(b) Drip irrigation

Fertilizers

Fertilizers supply nutrients to crops.

- **Inorganic fertilizers** = mined or synthetically manufactured mineral supplements
- **Organic fertilizers** = animal manure, crop residues, compost, etc.

Fertilizers

- The use of inorganic fertilizer grew enormously between 1960 and 1990, and we now apply 150 metric tons per year.
- Its use has greatly boosted global food production.
- But overuse causes severe pollution problems, such as the Gulf of Mexico “dead zone” discussed in Chapter 3.

Overgrazing

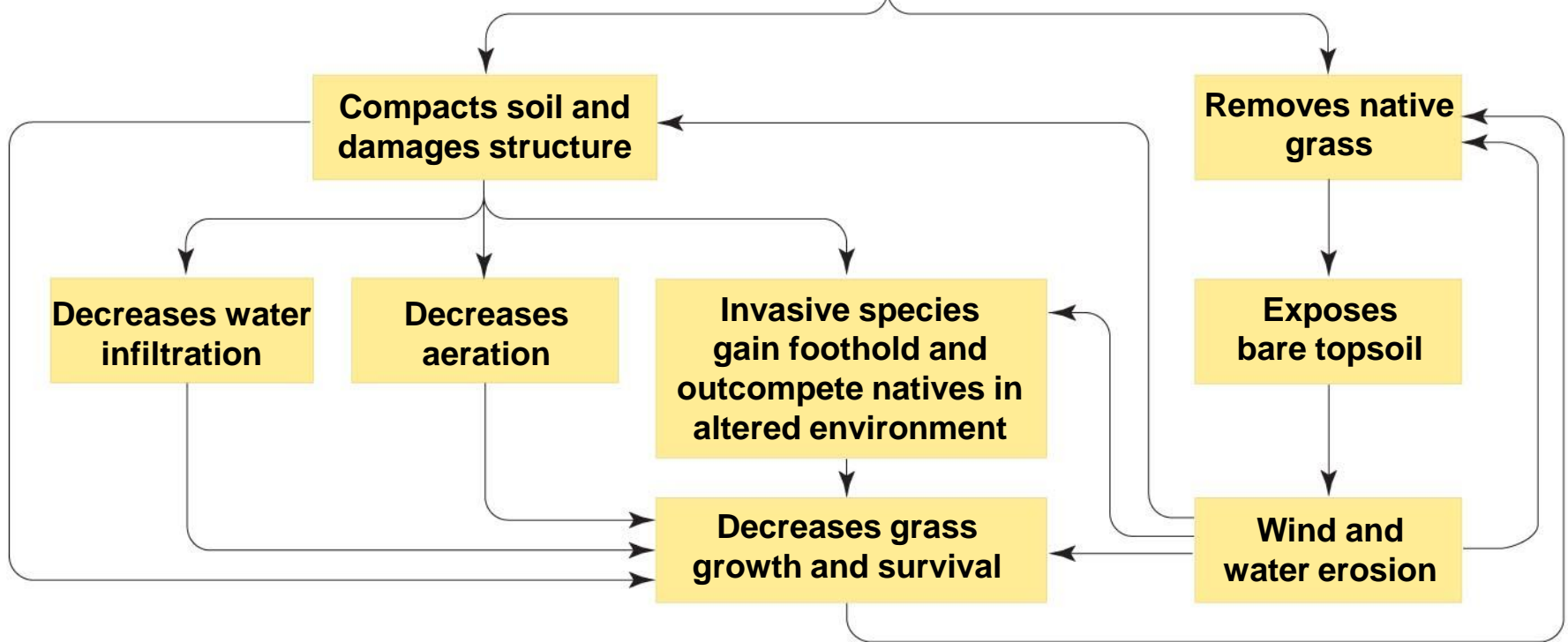
- Overgrazing occurs when livestock eat too much plant cover on rangelands, impeding plant regrowth.
- As a cause of soil degradation worldwide, overgrazing is equal to cropland agriculture and is a greater cause of desertification.

Overgrazing

Overgrazing can set in motion a series of positive feedback loops.



Overgrazing



Recent soil conservation laws

The United States has continued to pass soil conservation legislation in recent years:

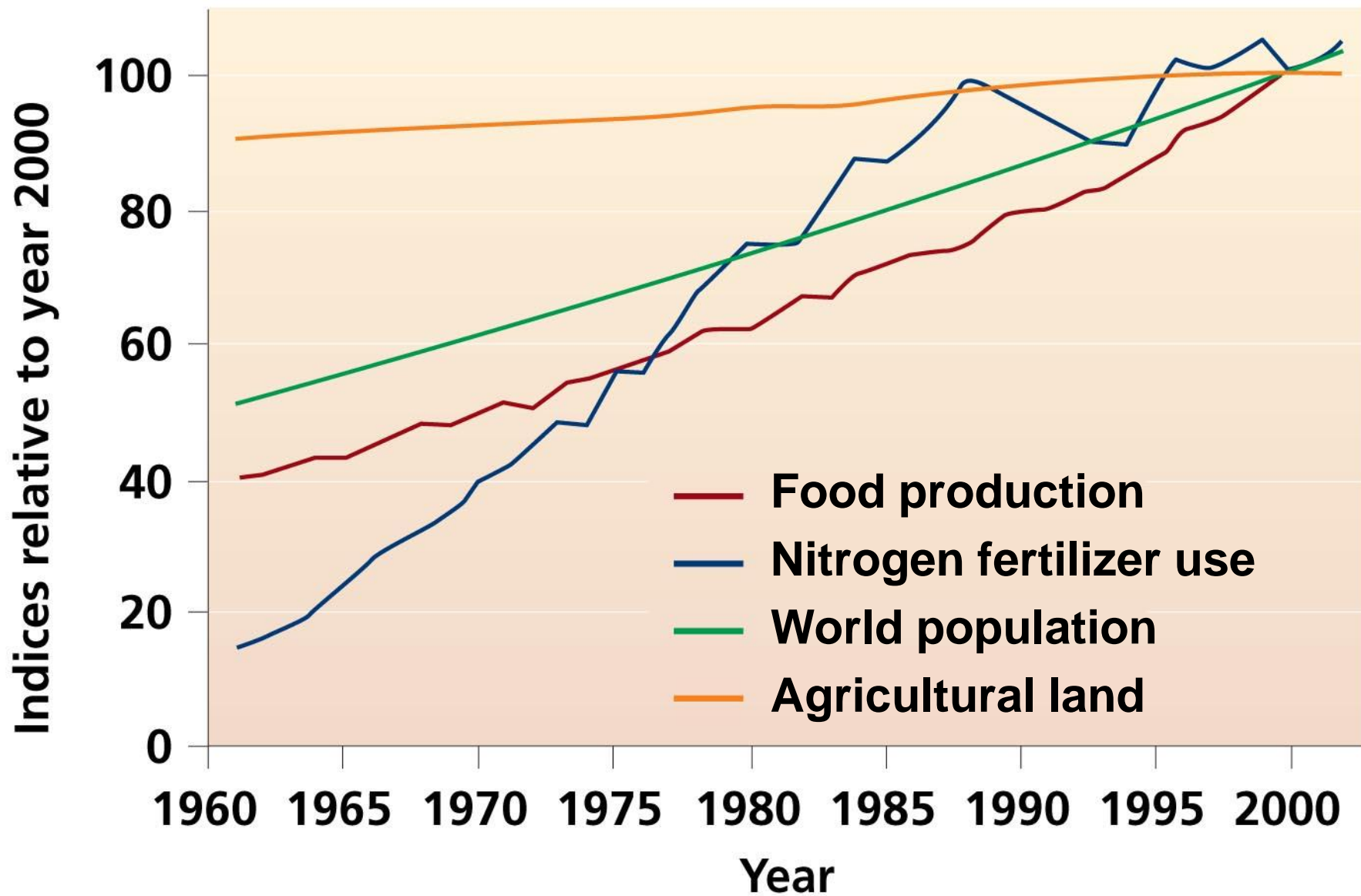
- Food Security Act of 1985
- Conservation Reserve Program, 1985
- Freedom to Farm Act, 1996
- Low-Input Sustainable Agriculture Program, 1998

The race to feed the world

- Although human population growth has slowed, we can still expect our numbers to grow.
- More people will require more food.
- Our ability to produce food has grown even more quickly than the human population.

Global food production

World agricultural production has risen faster than the human population.



Global food security

- However, the world still has 850 million hungry people, largely due to inadequate distribution.
- And considering soil degradation, can we count on food production continuing to rise?
- Global **food security** is a goal of scientists and policymakers worldwide.

Nutrition

Undernourishment =
too few calories
(especially developing world)

Overnutrition =
too many calories
(especially developed world)

Malnutrition = lack of
nutritional requirements
*(causes numerous diseases,
especially in developing world)*



The green revolution

- Efforts have been made to increase crop output per unit area of cultivated land (because the world was running out of arable land).
- Technology transfer to the developed world in the 1940s–1980s: *Norman Borlaug began in Mexico, then India.*
- Special crop breeds (drought-tolerant, salt-tolerant, etc.) are a key component.
- These measures enabled food production to keep pace with population.

Green revolution: Environmental impacts

The intensification of agriculture causes environmental harm:

- Pollution from synthetic fertilizers
- Pollution from synthetic pesticides
- Water depleted for irrigation
- Fossil fuels used for heavy equipment

However, without the green revolution, much more land would have been converted for agriculture, destroying forests, wetlands, and other ecosystems.

Monocultures

- Intensified agriculture meant **monocultures**, vast spreads of a single crop.
- This is economically efficient but increases the risk of catastrophic failure (“all eggs in one basket”).
- Monocultures also have reduced crop diversity and biodiversity.

Pesticides

- Artificial chemicals have been developed to kill insects (*insecticides*), plants (*herbicides*), and fungi (*fungicides*).
- These poisons are collectively called **pesticides**.
- Many pests evolve resistance to pesticides.

Chemical pesticides

Synthetic poisons that target organisms judged to be pests.

**Table 7.1 Most Commonly Used Pesticides*
in Agriculture in the United States**

Active ingredient [†]	Type of pesticide	Millions of kg applied per year
Glyphosate	Herbicide	39–41
Atrazine	Herbicide	34–36
Metam sodium	Fumigant	26–28
Acetochlor	Herbicide	14–16
2,4-D	Herbicide	13–15
Malathion	Insecticide	9–11
Methyl bromide	Fumigant	9–11
Dichloropropene	Fumigant	9–11
Metolachlor-s	Herbicide	9–11
Metolachlor	Herbicide	7–10

*Includes only “conventional pesticides” used in agriculture. Does not include many other types of pesticides, such as disinfectants and wood preservatives.

[†]Includes only active ingredients, not ingredients such as oil, sulfur, and sulfuric acid.

Data from Kiely, T., et al. 2004. *Pesticides industry sales and usage: 2000 and 2001 market estimates*. Washington, DC: U.S. Environmental Protection Agency.

Pests evolve resistance to pesticides

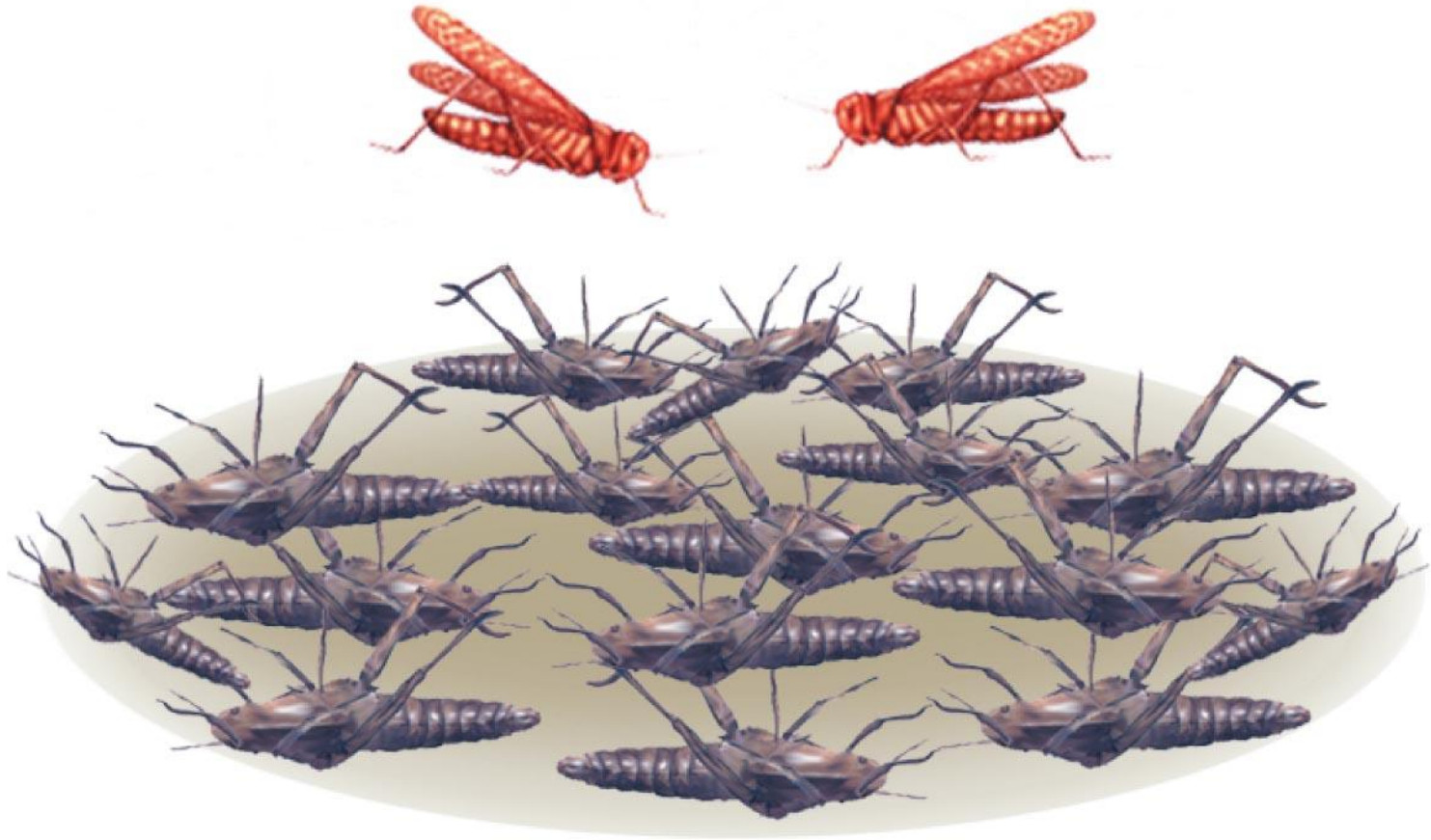
- Pesticides gradually become less effective, because pests evolve resistance to them.
- Those few pests that survive pesticide applications because they happen to be genetically immune will be the ones that reproduce and pass on their genes to the next generation.
- This is evolution by natural selection, and it threatens our very food supply.



1 Outbreak of pests on crops



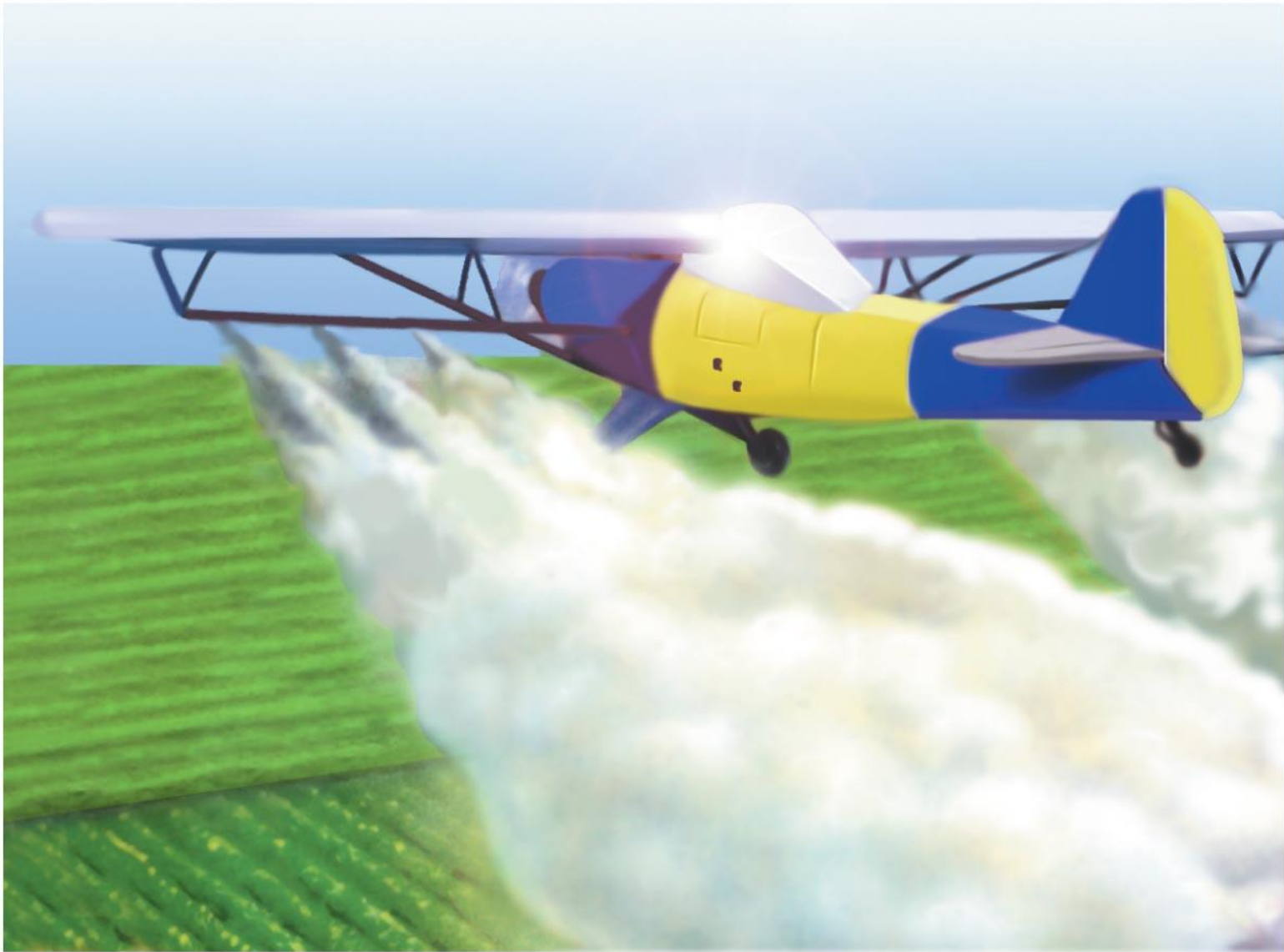
2 Application of pesticide



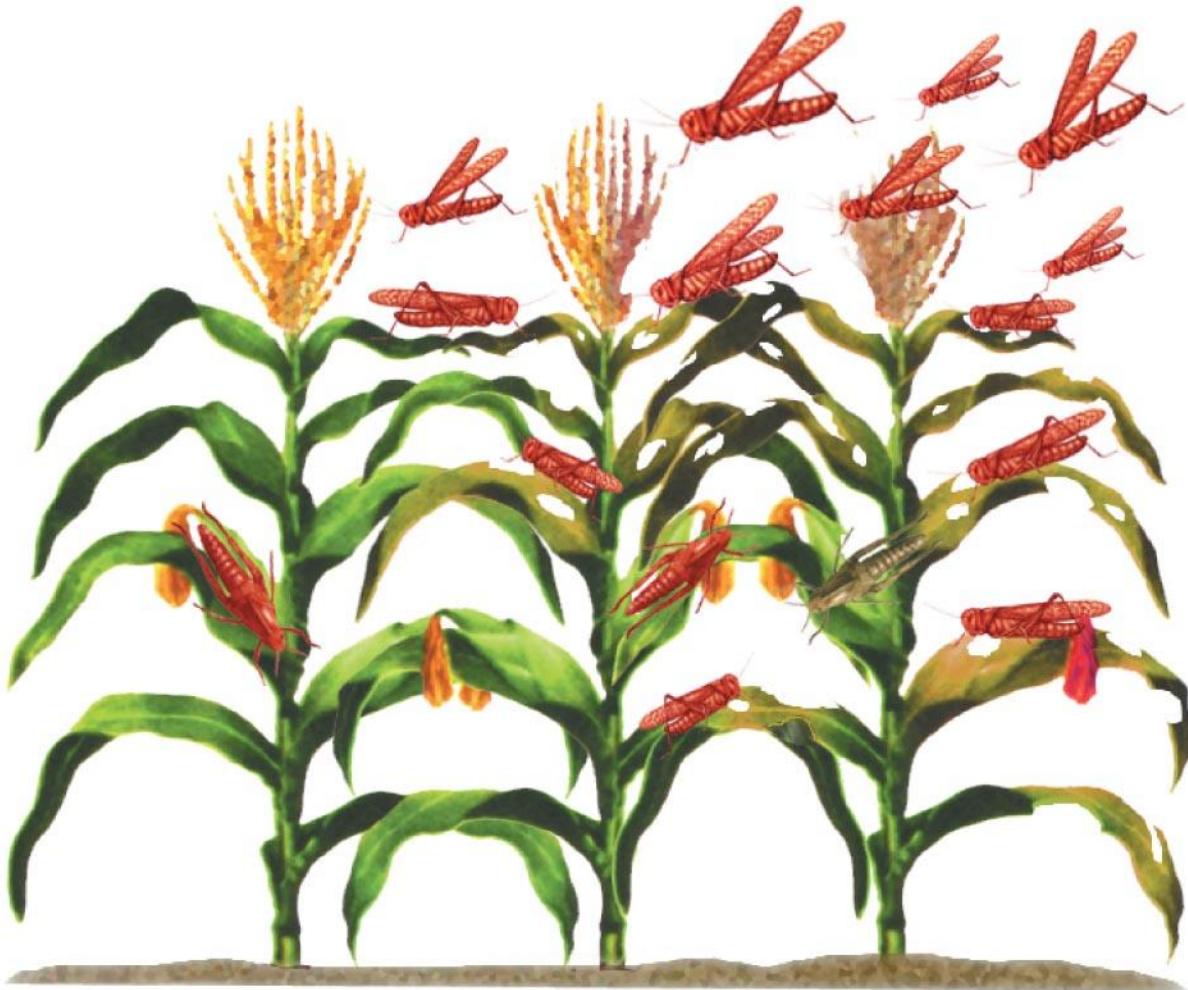
3 All pests except a few with innate resistance are killed



4 Survivors breed and produce a pesticide-resistant population



5 Pesticide is applied again



**6 Pesticide has little effect
and new, more toxic pesticides
must be developed**

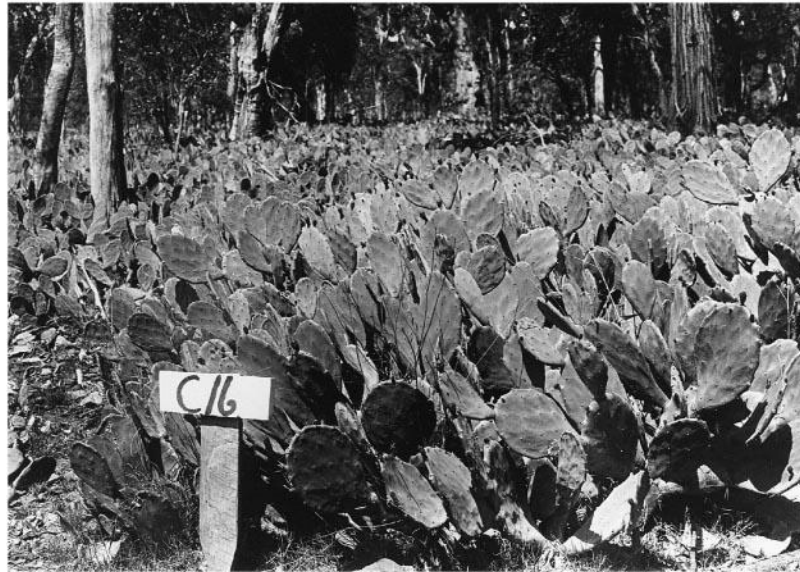
Biological control

- Synthetic chemicals can pollute and be health hazards.
- **Biological control (biocontrol)** avoids this.
- Biocontrol entails battling pests and weeds with other organisms that are natural enemies of those pests and weeds.
- (*“The enemy of one’s enemy is one’s friend.”*)

Biological control

Biocontrol has had success stories.

- **Bacillus thuringiensis (Bt)** = soil bacterium that kills many insects
- Cactus moth, **Cactoblastis cactorum**, was used to wipe out invasive prickly pear cactus in Australia.



(a) Before cactus moth introduction



(b) After cactus moth introduction

But biocontrol is risky

- Most biocontrol agents are introduced from elsewhere.
- Some may turn invasive and become pests themselves!

Cactus moths brought to the Caribbean jumped to Florida, are eating native cacti, and are spreading.

Integrated pest management (IPM)

Combines biocontrol, chemical, and other methods

May involve:

- Biocontrol
- Pesticides
- Close population monitoring
- Habitat modification
- Crop rotation
- Transgenic crops
- Alternative tillage
- Mechanical pest removal

IPM successes

Indonesia turned to IPM and increased rice production while decreasing pesticide production and eliminating pesticide subsidies.

Pollination

- Pollination is the process of plant reproduction: male pollen meets female sex cells.
- In many plants, animals transfer pollen in a mutualistic interaction while trying to obtain nectar or pollen.
- Pollinating insects are vital for many of our crop plants.

Pollinator conservation

European honeybees commercially used to pollinate crop plants have been hit hard by parasites lately.



So it's important to conserve native bees and other insects that pollinate crop plants naturally.

The overuse of pesticides can backfire by killing beneficial pollinators.

Genetic modification of food

- Manipulating and engineering genetic material in the lab may represent the best hope for increasing agricultural production further without destroying more natural lands.
- But many people remain uneasy about genetically engineering crop plants and other organisms.

Genetic engineering uses recombinant DNA

- **Genetic engineering (GE)** = directly manipulating an organism's genetic material in the lab by adding, deleting, or changing segments of its DNA
- **Genetically modified (GM) organisms** = genetically engineered using recombinant DNA technology
- **Recombinant DNA** = DNA patched together from DNA of multiple organisms (e.g., adding disease-resistance genes from one plant to the genes of another)

Transgenes and biotechnology

- Genes moved between organisms are **transgenes**, and the organisms are **transgenic**.
- These efforts are one type of **biotechnology**, the material application of biological science to create products derived from organisms.

Genetic engineering vs. traditional breeding

They are similar:






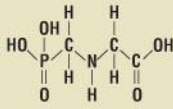
- We have been altering crop genes (by artificial selection) for thousands of years.
- Both approaches modify organisms genetically.

They are different:

- GE can mix genes of very different species.
- GE is *in vitro* lab work, not with whole organisms.
- GE uses novel gene combinations that didn't come together on their own.

Some GM foods

The early development of genetically modified foods was marked by a number of cases in which these products ran into trouble.

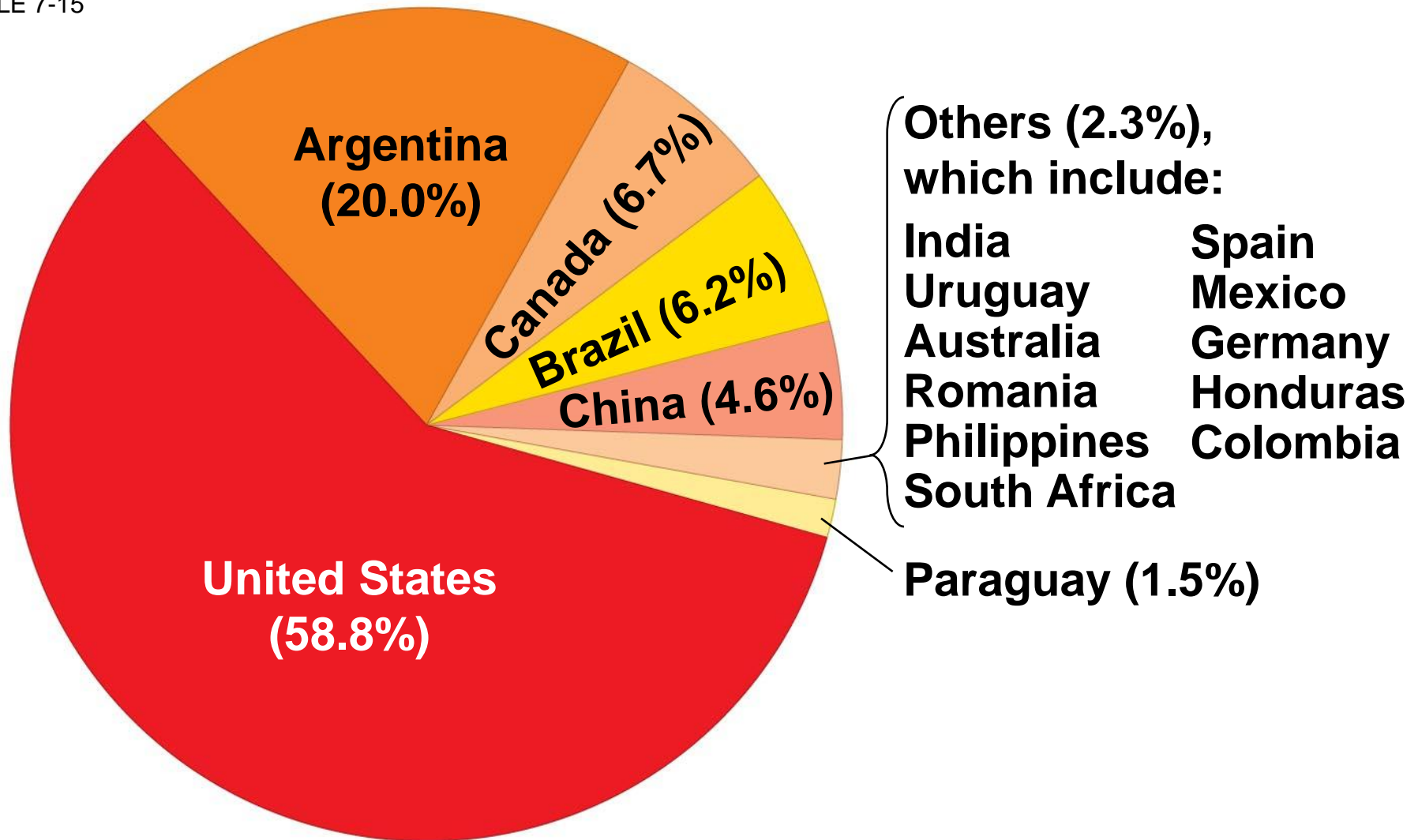
Food	Development	Food	Development
<p>Golden rice</p> 	<p>Millions of people in the developing world get too little vitamin A in their diets causing diarrhea, blindness, immune suppression, and even death. The problem is worst with children in East Asia, where the staple grain, white rice, contains no vitamin A. Researchers took genes from plants that produce vitamin A and spliced the genes into rice DNA to create more-nutritious “golden rice” (the vitamin precursor gives it a golden color). Critics charged that biotech companies over-hyped their product.</p>	<p>StarLink corn</p> 	<p>StarLink corn, a variety of Bt corn, had been approved and used in the United States for animal feed but not for human consumption. In 2000, StarLink corn DNA was discovered in taco shells and other corn products. These products were recalled amid fears that the corn might cause allergic reactions. No such health effects were confirmed, but the corn’s French manufacturer, Aventis Crop Science, chose to withdraw the product from the market.</p>
<p>Ice-minus strawberries</p> 	<p>Researchers removed a gene that facilitated the formation of ice crystals from the DNA of a bacterium, <i>Pseudomonas syringae</i>. The modified, frost-resistant bacteria could then serve as a kind of antifreeze when sprayed on the surface of frost-sensitive crops such as strawberries, protecting them from frost damage. However, news coverage showed scientists spraying plants while wearing face masks and protective clothing, an image that caused public alarm.</p>	<p>Sunflowers and superweeds</p> 	<p>Research on Bt sunflowers suggests that their transgenes might spread to other plants and turn them into vigorous weeds that compete with the crop. This is most likely to happen with crops like squash, canola, and sunflowers that can breed with their wild relatives. Researchers bred wild sunflowers with Bt sunflowers and found that hybrids with the Bt gene produced more seeds and suffered less herbivory than hybrids without it. They concluded that if Bt sunflowers were planted commercially, the Bt gene would spread into wild sunflowers, potentially turning them into superweeds.</p>
<p>Bt crops</p> 	<p>By equipping plants with the ability to produce their own pesticides, scientists hoped to boost crop yields by reducing losses to insects. Scientists working with <i>Bacillus thuringiensis</i> (Bt) pinpointed the genes responsible for producing that bacterium’s toxic effects on insects, and inserted the genes into the DNA of crops. The USDA and EPA approved Bt versions of 18 crops for field testing, from apples to broccoli to cranberries. Corn and cotton are the most widely planted Bt crops today. Proponents say Bt crops reduce the need for chemical pesticides. Critics worry that they will induce insects to evolve resistance to the toxins, cause allergic reactions in humans, and harm nontarget species.</p>	<p>Roundup Ready crops</p> 	<p>The Monsanto Company’s widely used herbicide, Roundup, kills weeds, but it kills crops too, so farmers must apply it carefully. Thus, Monsanto engineered Roundup Ready crops, including soybeans, corn, cotton, and canola, that are immune to the effects of its herbicide. With these variants, farmers can spray Roundup on their fields without killing their crops. Of course, this also creates an incentive for farmers to use Monsanto’s Roundup herbicide rather than a competing brand. Unfortunately, Roundup is not completely benign; its active ingredient, glyphosate, is the third-leading cause of illness for California farm workers.</p>

Prevalence of GM foods

- Although many early GM crops ran into bad publicity or other problems, biotechnology is already transforming the U.S. food supply.
- *Two-thirds of U.S. soybeans, corn, and cotton are now genetically modified strains.*

Leading producers of GM foods

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Transgenic contamination?



- UC Berkeley researchers Ignacio Chapela (L) and David Quist (R) ignited controversy by claiming contamination of native Mexican maize.
- They later admitted some flaws in their methods, but debate continued, revealing the personal and political pressures of high-stakes scientific research.

Scientific concerns about GM organisms

- Are there health risks for people?
- Can transgenes escape into wild plants, pollute ecosystems, or harm organisms?
- Can pests evolve resistance to GM crops just as they can to pesticides?
- Can transgenes jump from crops to weeds and make them into “superweeds”?
- Can transgenes get into traditional native crop races and ruin their integrity?

Scientific concerns about GM organisms

- These questions are not yet fully answered.
- In the meantime...

Should we not worry, because so many U.S. crops are already GM and little overt harm is apparent?

Or should we adopt the **precautionary principle**, the idea that one should take no new action until its ramifications are understood?

Socioeconomic and political concerns about GM products

- Should scientists and corporations be “tinkering with” our food supply?
- Are biotech corporations testing their products adequately, and is outside oversight adequate?
- Should large multinational corporations exercise power over global agriculture and small farmers?

Europe vs. America

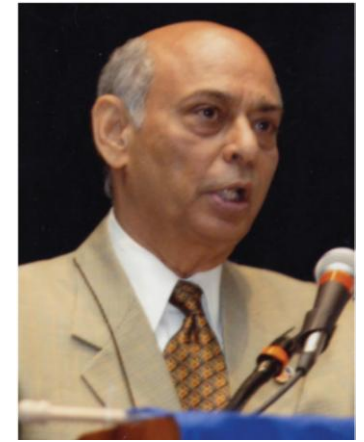
- In **European countries**, the precautionary principle has been followed in the approach to GM foods. Governments have listened to popular opposition and enacted labeling laws.
- In the **United States**, GM foods were introduced and accepted with relatively little public debate.
- Relations over agricultural trade have been uneasy, and it remains to be seen whether Europe will accept more GM foods from the United States.

Viewpoints: Genetically modified foods



Ignacio
Chapela

“We should expect fundamental alterations in ecosystems with the release of transgenic crops... We are experiencing a global experiment without controls.”



Indra
Vasil

“Biotech crops are already helping to conserve valuable natural resources, reduce the use of harmful agro-chemicals, produce more nutritious foods, and promote economic development.”

Preserving crop diversity

- Native cultivars of crops are important to preserve, in case we need their genes to overcome future pests or pathogens.
- The diversity of cultivars has been rapidly disappearing from all crops throughout the world.
- Many scientists argue that we need to protect important areas from GM crops to retain repositories of crop diversity.

Seed banks preserve seeds, crop varieties

Seed banks are living museums of crop diversity, saving collections of seeds and growing them into plants every few years to renew the collection.

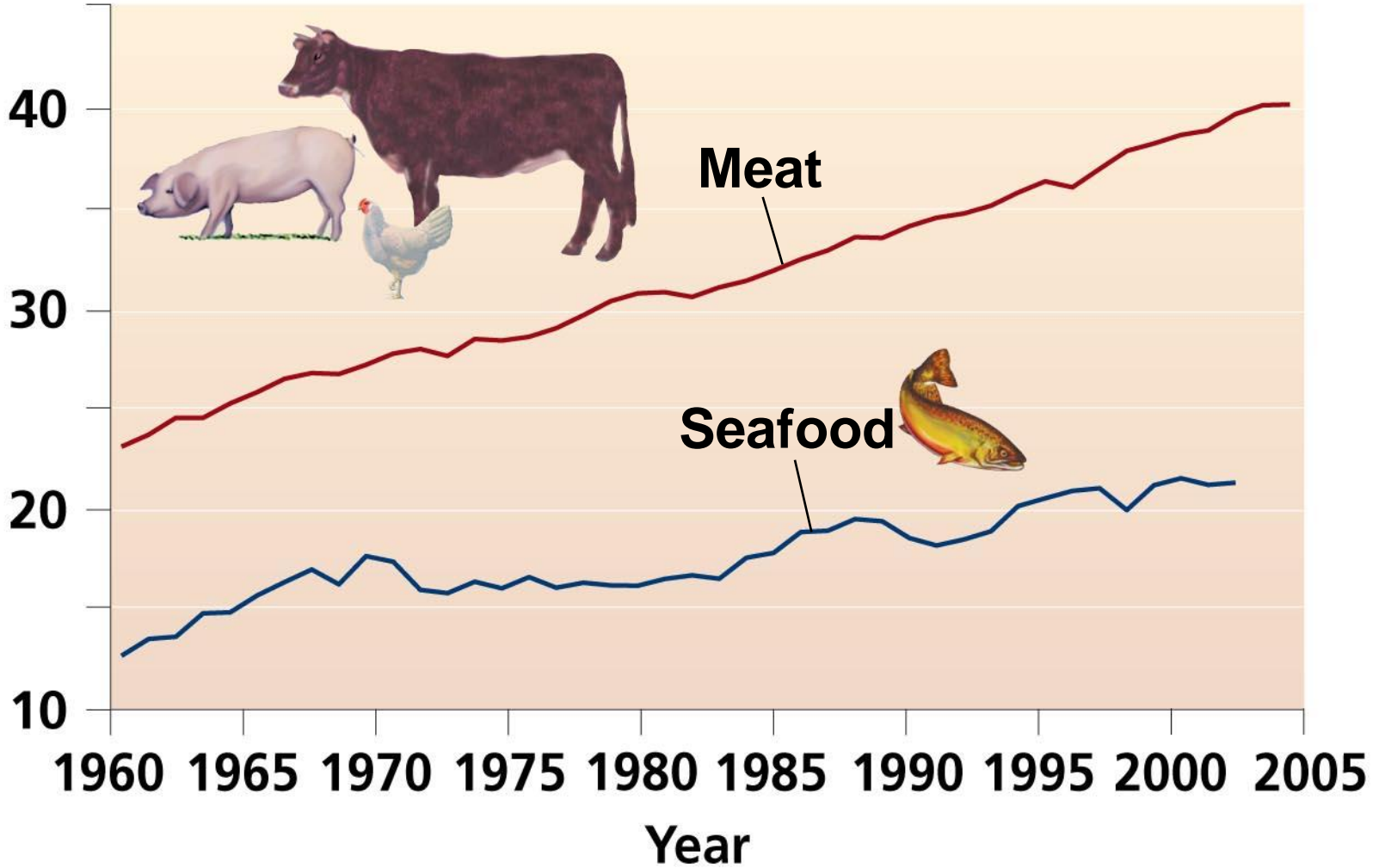
Careful hand pollination at this seed bank in Arizona helps ensure that plants of one type do not interbreed with plants of another.



Animal agriculture: Livestock and poultry

Consumption of meat has risen faster than population over the past several decades.

**World seafood and meat production
(kg per person per year)**



Feedlot agriculture

Increased meat consumption has led to animals being raised in **feedlots (factory farms)**, huge pens that deliver energy-rich food to animals housed at extremely high densities.



Feedlot agriculture: Environmental impacts

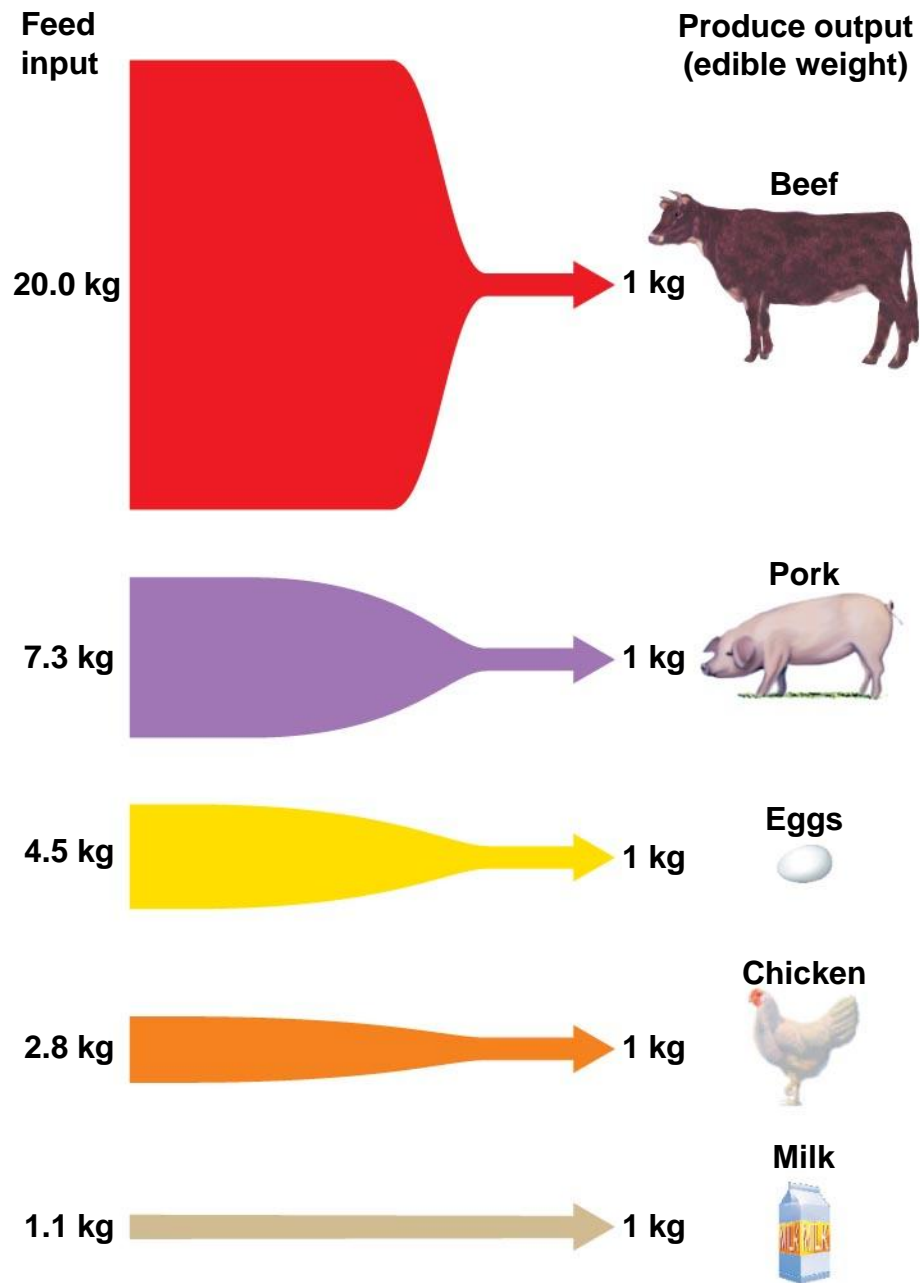
- Immense amount of waste produced, polluting air and water nearby
- Intense usage of chemicals (antibiotics, steroids, hormones), some of which persist in the environment
- *However, if all these animals were grazing on rangeland, how much more natural land would be converted for agriculture?*

Food choices = energy choices

- Energy is lost at each trophic level.
- When we eat meat from a cow fed on grain, most of the grain's energy has already been spent on the cow's metabolism.
- Eating meat is therefore very energy inefficient.

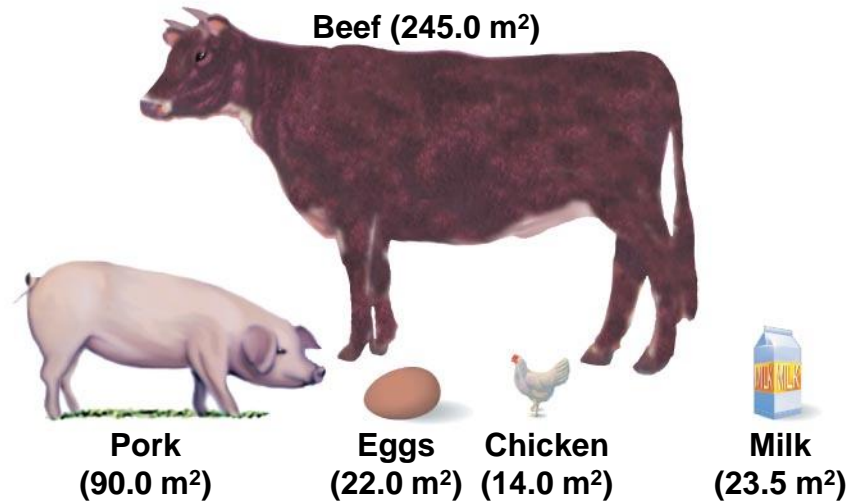
Grain feed input for animal output

Some animal food products can be produced with less input of grain feed than others.

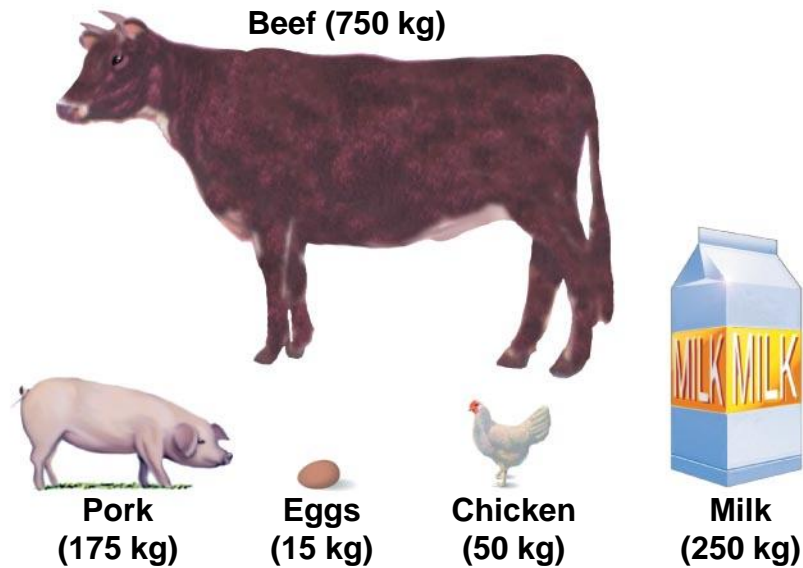


Land and water input for animal output

Some animal food products can be produced with less input of land and water than others.



(a) Land required to produce 1 kg of protein



(b) Water required to produce 1 kg of protein

Aquaculture

Aquaculture = raising aquatic organisms for food in controlled environments.

- Provides 1/3 of world's fish for consumption
- 220 species are being farmed
- The fastest growing type of food production

Benefits of aquaculture

- Provides a reliable protein source for people, increases food security
- Can be small-scale, local, and sustainable
- Reduces fishing pressure on wild stocks, and eliminates bycatch
- Uses fewer fossil fuels than fishing
- Can be very energy efficient

Environmental impacts of aquaculture

- The density of animals leads to disease, antibiotic use, and risks to food security.
- It can generate large amounts of waste.
- Animals are often fed grain, which is not energy efficient.
- Sometimes animals are fed fish meal from wild-caught fish.
- Farmed animals may escape into the wild and interbreed with, compete with, or spread disease to wild animals.

Environmental impacts of aquaculture



Transgenic salmon (top) can compete with or spread disease to wild salmon (bottom) when they escape from fish farms.

Sustainable agriculture

Agriculture that can be practiced the same way far into the future

- Does not deplete soils faster than they form.
- Does not reduce healthy soil, clean water, and genetic diversity essential for long-term crop and livestock production.

Low-input agriculture = small amounts of pesticides, fertilizers, water, growth hormones, fossil fuel energy, etc.

Organic agriculture = no synthetic chemicals used (instead, biocontrol, composting, etc.)

Organic farming

- In 2000, the USDA issued criteria by which crops and livestock could be officially certified as organic.
- Seventeen states have also set organic standards.

Organic farming

Small percent of market, but is growing fast:

- 1% of U.S. market, but growing 20%/yr
- 3–5% of European market, but growing 30%/yr

Organic produce:

- Advantages for consumers: healthier; environmentally better
- Disadvantages for consumers: less uniform and appealing-looking; more expensive

Locally supported agriculture

Through **community-supported agriculture**, consumers pay farmers for a share of their yield.



Farmers' markets have become more widespread.

Conclusion

- Many commercial agricultural practices have substantial negative environmental impacts.
- But, many aspects of industrialized agriculture have relieved pressure on land or resources.
- We must shift to sustainable agriculture if our planet is to support 9 billion people by mid-century without further environmental degradation.

QUESTION: Testing Your Comprehension

The A horizon in a soil profile... ?

- a.** Is often called the “zone of accumulation”
- b.** Is often called “topsoil”
- c.** Contains mostly organic matter
- d.** Is the lowest horizon, deepest underground

QUESTION: Testing Your Comprehension

The A horizon in a soil profile... ?

- b.** Is often called “topsoil”

QUESTION: Testing Your Comprehension

Erosion occurs through... ?

- a.** Deforestation
- b.** Excessive plowing
- c.** Overgrazing rangelands
- d.** All of the above

QUESTION: Testing Your Comprehension

Erosion occurs through... ?

d. All of the above

QUESTION: Testing Your Comprehension

Drip irrigation differs from conventional irrigation in that ... ?

- a.** It is much less efficient
- b.** It can cause salinization
- c.** Water is precisely targeted to plants
- d.** About 40% is wasted

QUESTION: Testing Your Comprehension

Drip irrigation differs from conventional irrigation in that ... ?

- c. Water is precisely targeted to plants

QUESTION: Testing Your Comprehension

Integrated pest management may involve all of the following EXCEPT... ?

- a.** Close population monitoring
- b.** Biocontrol
- c.** Exclusive reliance on pesticides
- d.** Habitat modification
- e.** Transgenic crops

QUESTION: Testing Your Comprehension

Integrated pest management may involve all of the following EXCEPT... ?

c. Exclusive reliance on pesticides

QUESTION: Testing Your Comprehension

Which statement is CORRECT?

- a.** Our ancestors used biotechnology in agriculture.
- b.** A transgenic organism contains DNA from another species.
- c.** Genetic engineering is limited to closely related species.
- d.** Recombinant DNA removes traits from an organism.
- e.** Genetic engineering is universally accepted.

QUESTION: Testing Your Comprehension

Which statement is CORRECT?

- b.** A transgenic organism contains DNA from another species.

QUESTION: Testing Your Comprehension

What do seed banks do?

- a.** Lend money to farmers to buy seeds
- b.** Pay farmers to store seeds
- c.** Buy seeds from farmers
- d.** Store seeds to maintain genetic diversity
- e.** None of the above

QUESTION: Testing Your Comprehension

What do seed banks do?

- d.** Store seeds to maintain genetic diversity

QUESTION: Seeking Solutions

How do you think a farmer can best help conserve soil?

How do you think a scientist can best help conserve soil?

How do you think a national government can best help?

QUESTION: Seeking Solutions

What factors make for an effective biological control strategy of pest management? What risks are involved in biocontrol? If you had to decide whether to use biocontrol against a particular pest, what questions would you want answered before you decide?

QUESTION: Seeking Solutions

Imagine it is your job to make a regulatory decision whether to allow the planting of a new genetically modified strain of cabbage that produces its own pesticides and twice the vitamin content of regular cabbage. What questions would you ask of scientists before deciding? Beyond science, what other factors might you consider, if any?

QUESTION: Viewpoints

Should we encourage the continued development of GM foods?

- a.** Yes; they will bring many health, social, and environmental benefits.
- b.** No, we should adopt the precautionary principle and not introduce novel things until we know they are safe.
- c.** Yes, but we should proceed cautiously and consider each new crop separately.