Feeding The World

Chapter 11

IV. Land and Water Use (10-15%)

A. Agriculture

F. Fishing

Module 31: Human Nutritional Needs

After this module you will be able to……

1) Describe human nutritional requirements
2) Explain why nutritional requirements are not being met in various parts of the world

Human Nutrition Requirements

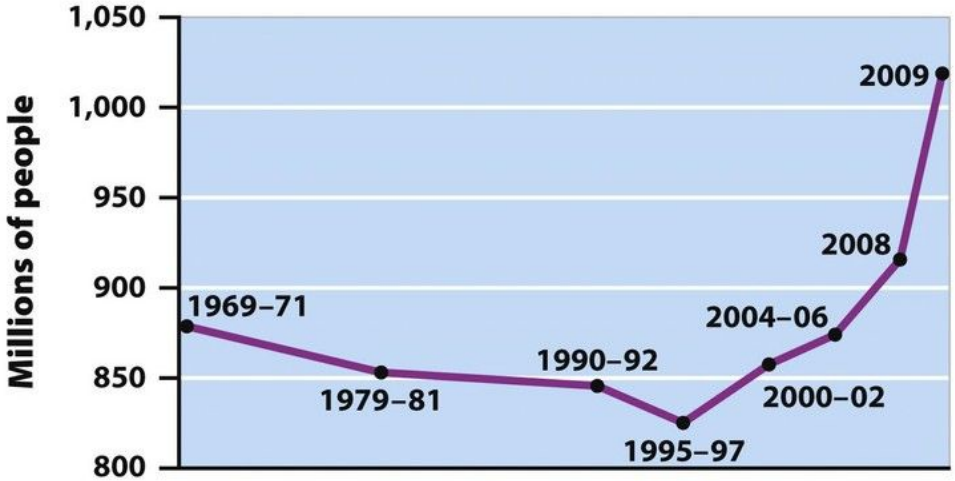


Figure 11.1 **Global undernutrition.** The number of undernourished people declined throughout the 1970s and 1980s, reaching a low of about 800 million in 1996. Since that time, it has risen. [After http://www.imf.org/external/pubs/ft/fandd/2010/03/picture.htm.]

Over the past 10,000 years, we have made advancements in agriculture that have greatly improved human diet. However, there are still many people throughout the world that do not receive adequate nutrition. Currently, about 24,000 people starve to death each day, or 8.8 million people each year.

Human Nutrition Requirements

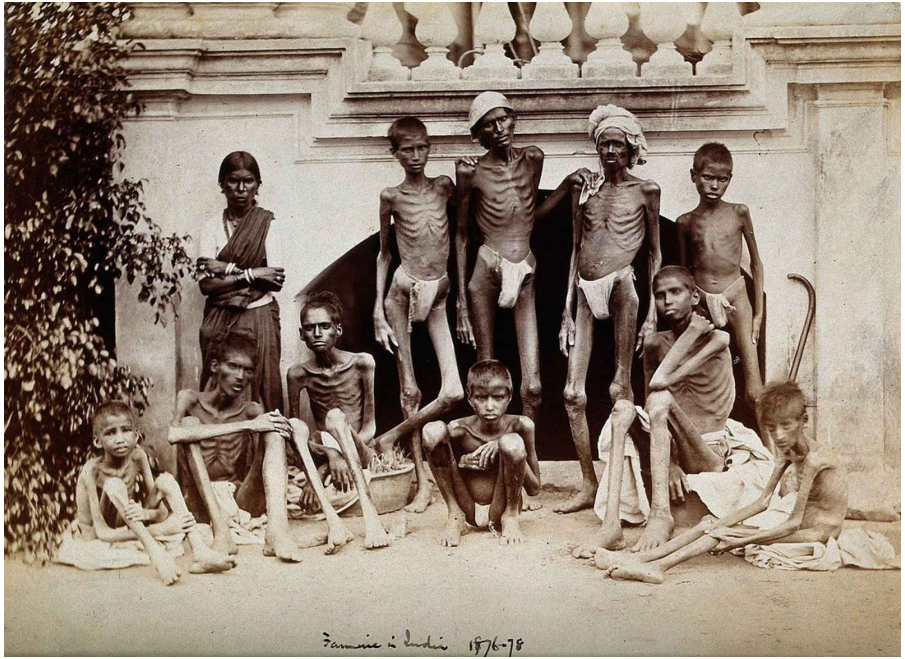
Undernutrition is a condition in which not enough calories are ingested to maintain health. Since calories are used for energies, not receiving enough leads to energy deficit. An average person needs approximately 2,000 kilocalories per day, but note that this amount varies with gender, age, and weight. In children, undernutrition can lead to improper brain development and lower IQ.

Even if you are receiving the correct number of calories, you may not be receiving the correct balance of proteins, carbohydrates, vitamins, and minerals. This is known as **malnourished**. According to the Global Nutrition Report 2017, roughly 2.5 billion people in the world (roughly ⅓) are malnourished and experience malnutrition.

Human Nutrition Requirements

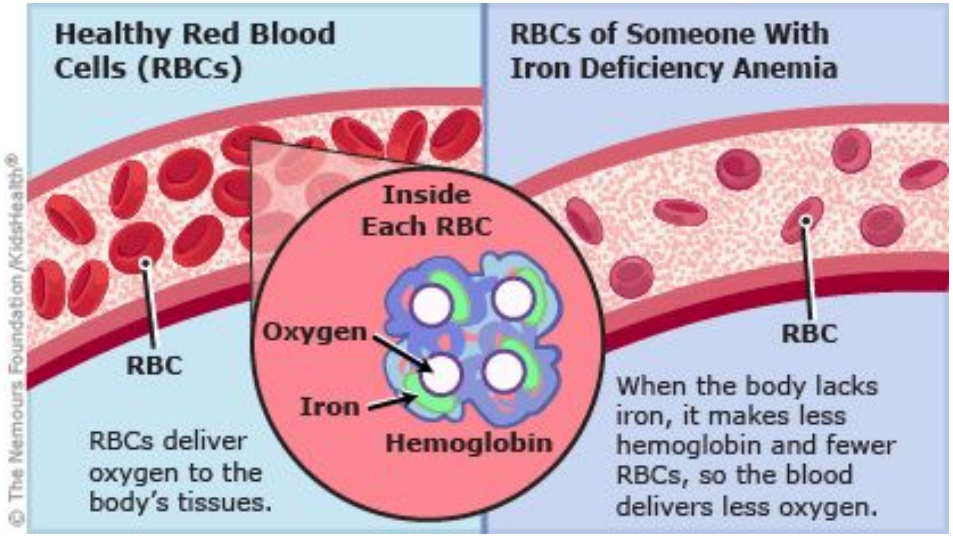
Food security is a condition in which people have access to sufficient, safe, and nutritious food that meets their dietary needs for an active and healthy life. On the contrary, **food insecurity** is a condition in which people do not have adequate access to food. Both these terms are defined by The Food and Agriculture Organization of the United Nations (FAO).

Human Nutrition Requirements



Famine is a condition in which food insecurity is so extreme that large numbers of deaths occur in a given area over a relatively short period. Famine are often caused by crop failures, but they can also have social and political causes.

Human Nutrition Requirements



Note that even if you have access to sufficient food, a deficit in just one essential vitamin or mineral can have drastic consequences. The WHO estimates that more than 250,000 children per year become blind due to a vitamin A deficiency. Iron deficiency, known as **anemia**, is the most widespread nutritional deficiency in the world. The WHO estimates there are 2 billion anemic people in the world, most in developing countries. Causes of anemia include not only lack of dietary iron, but diseases such as malaria and AIDS as well as parasite infestations.

Human Nutrition Requirements

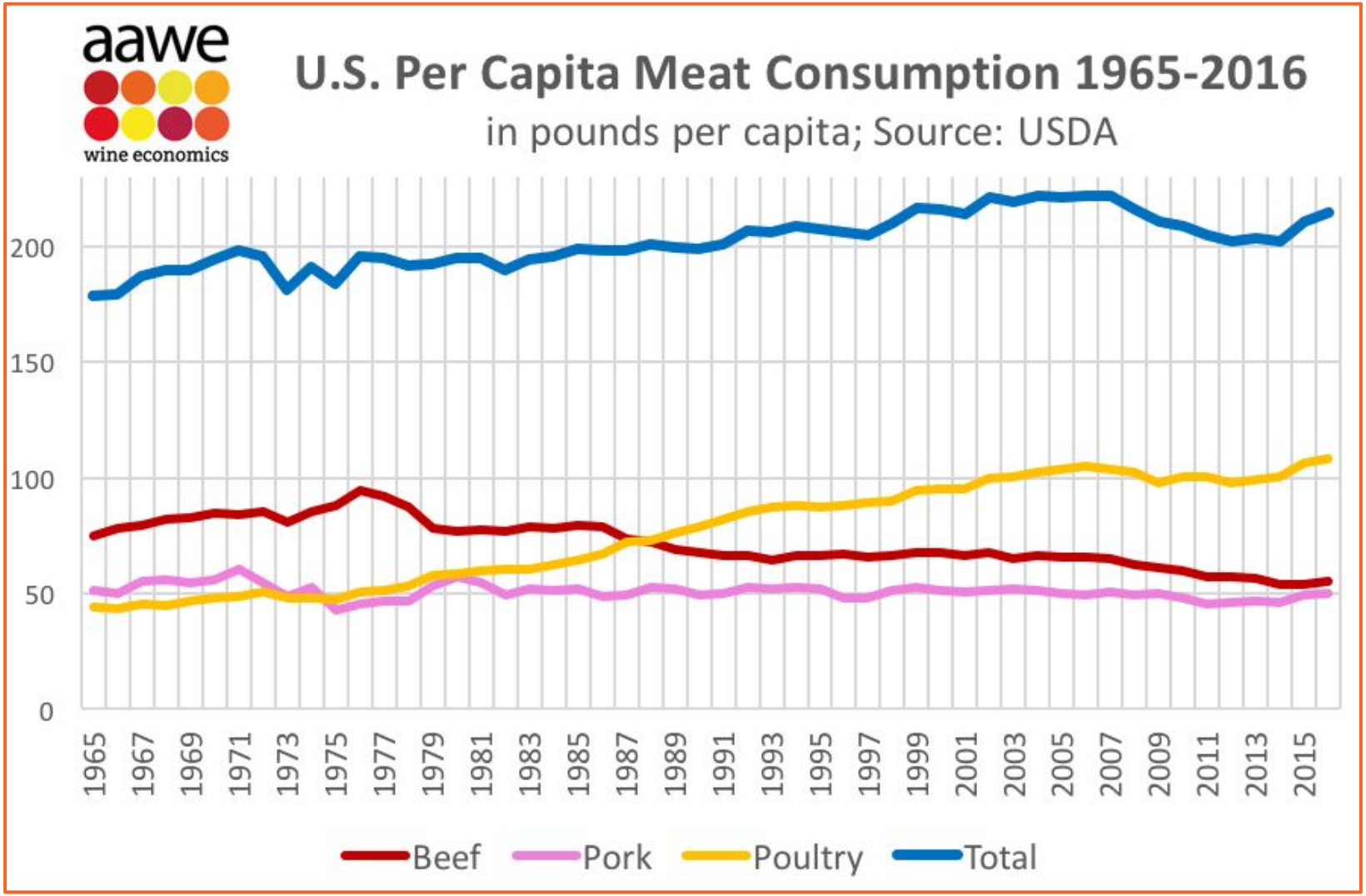
Too many calories combined with a lack of proper balance in foods and nutrients is known as **overnutrition**. This causes a person to be overweight and malnourished. The WHO estimates that there are almost 2 billion adults in the world who are overweight, and that roughly 600 million of these people are obese, meaning they are more than 20 percent above their ideal weight.

Overnutrition puts people at risk of a variety of diseases such as type 2 diabetes, hypertension, heart diseases, and stroke. It's common in developed and developing countries. One reason overnutrition occurs is because of the availability and affordability of certain kinds of food.

Human Nutrition Requirements

Although humans eat a variety of foods, grains make up the largest component of the human diet. Worldwide there are roughly 50,000 edible plant species, but just three of them (corn, rice, and wheat) constitute half of human energy intake.

Meat is the second largest component of the human diet and is usually defined as livestock, such as beef, veal, pork, and lamb, and poultry, such as turkey, chicken, and duck. Typically, as income increases with economic growth the amount of meat added to the diet increases.


aawe
wine economics
U.S. Per Capita Meat Consumption 1965-2016
in pounds per capita; Source: USDA
200
150
100
50
0
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Beef
Pork
Poultry
Total

Nutrition and Poverty

Currently, the world's farmers grow enough grain to feed at least 8 billion people, which would appear to be more than enough for the world's population of 7.1 billion. Grain is also only a little more than half of the total amount of food we produce, in terms of caloric content and biomass. These leads us to wonder why there are so many people who suffer from malnutrition and undernutrition.

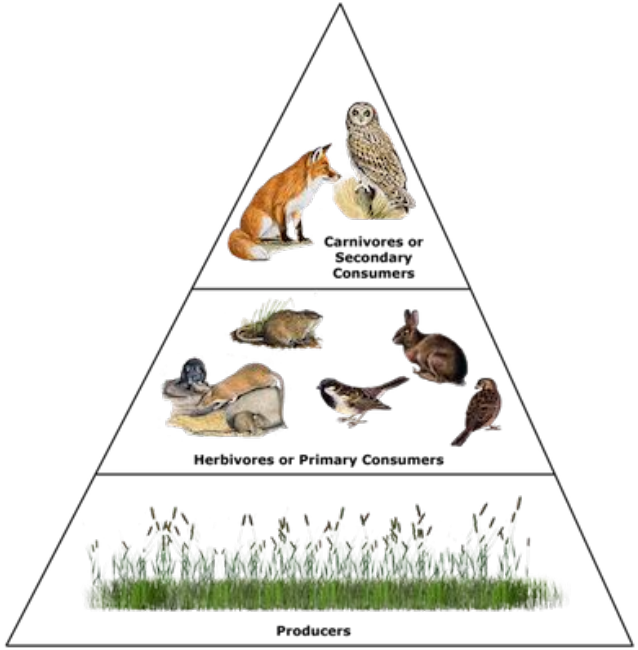
The primary reason for undernutrition and malnutrition is poverty, or the lack of resources that allow a person to have access to food. According to many food experts, starvation on a global scale is the result of unequal distribution of food rather than absolute scarcity of food.

Nutrition and Poverty

Political factors can also be the cause of poor nutrition. In 2008, a high rise in food prices led to food riots in Haiti, Egypt, Ivory Coast, Cameroon, Yemen, and elsewhere.

In 2017 food shortages caused by government agriculture policies led to rioting and death in Venezuela.

Nutrition and Poverty



Food researches have also observed that large amounts of agricultural resources are diverted to feed livestock and poultry rather than people. Roughly 40 percent of the grain grown in the world is used to feed livestock. Ultimately, only about 10-15 percent of the calories in grain or soybeans fed to the cattle are converted into calories in beef. If people ate producers over consumers, it's possible that more food would be available, which is a concept referred to as "*eating lower on the food chain.*"

Module 32: Modern Large-Scale Farming Methods

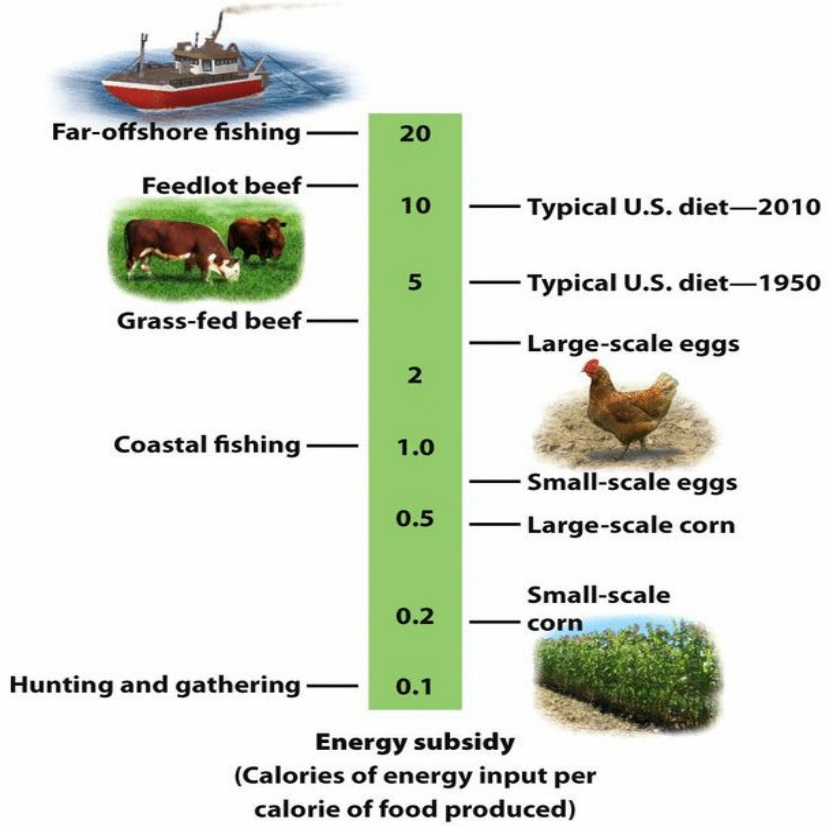
After this module you will be able to……

1) Describe modern, large-scale agricultural methods
2) Explain the benefits and consequences of genetically modified organisms
3) Discuss the large-scale raising of meat and fish

Modern Industrial Farming Methods

In the 20th century farming became more mechanized and the use of fossil fuels to produce food has increased. This has led to increased food output as well as a variety of environmental impacts. **Industrial agriculture**, or **agribusiness**, is agriculture that applies the techniques of mechanization and standardization. This section focuses on how modern industrial agriculture is dependent on energy and what activities the additional energy inputs allow.

Modern Industrial Farming Methods



Energy subsidy is the fossil fuel energy and human energy input per calorie of food produced. In other words, if we use 5 calories of human and fossil fuel energy to produce food, and we receive 1 calorie of energy when we eat that food, then the food has an energy subsidy of 5.

On a larger scale, if it takes 20 kg of grain to feed cattle to produce 1 kg of beef, then the energy subsidy is 20. However, if it only takes 2.8 kg of grain to feed chickens to produce 1 kg of chicken meat, then the energy subsidy is 2.8 which is considerably smaller than the energy subsidy for beef.

Modern Industrial Farming Methods

How is energy being used? Most energy comes from fossil fuels and is used to produce fertilizers and pesticides, operate tractors, to pump water for irrigation, and to harvest food and prepare it for transport. Other energy subsidies take place off the farm. For example, the average food item travels 2,000 km from the farm to your plate.

Do the Math

On farms in the midwestern United States, a hectare of land yields roughly 370 bushels of corn (equivalent to 150 bushels per acre). A bushel consists of 1,250 ears of corn, and each ear typically contains 80 kilocalories. Assume that a person eats only corn and requires 2,000 kilocalories per day. Although this assumption is not very realistic, it allows an approximation of how much land it would take to feed that person.

The person's food requirement is:
2,000 kilocalories/day x 365 days/year = 730,000 kilocalories/year

A hectare of corn produces:
370 bushels/hectare x 1,250 ears/bushel x 80 kilocalories/year = 37,000,000 kilocalories/hectare
730,000 kilocalories/year ÷ 37,000,000 kilocalories/hectare = 0.02 ha (0.05 acres) of land to feed one person for a year.

Do the Math

What if the person ate only beef? Since it has an energy subsidy of 20, we know that it will take 20 times as much land, or 0.4 ha to feed a person who only ate beef.

Note that this is just the amount of land per person. Let's now extend this to a global scale. Earth has about 1.5 billion ha of land suitable for growing food, is there sufficient land to feed all 6.8 billion people of the planet if they eat only beef?

6.8 billion people x 0.4 ha/person = 2,720,000,000 ha.
There is not enough land to support the world eating only beef!

Your Turn

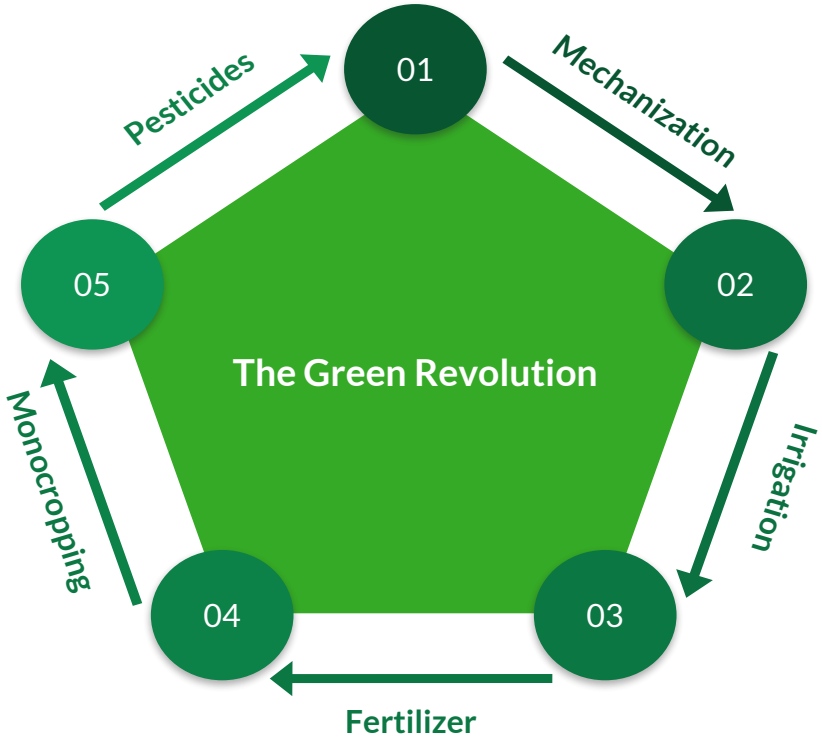
How many people eating a beef-only diet can Earth support?

The Green Revolution

The **Green Revolution** is a shift in agricultural practices in the 20th century that included new management techniques, mechanization, fertilization, irrigation, and improved crop varieties, that resulted in increased food output. This transition is due to crop scientists, particularly Norman Borlaug (1914-2009), who developed strains of wheat that were disease resistant and produced higher yields. These techniques were brought to Mexico and the Philippines and helped increase their agricultural output to feed their growing populations.

The Green Revolution

Although the Green Revolution helped feed the world, it had some negative impacts.



The Green Revolution - Mechanization

Machines don't necessarily do work better than humans or animals, but it can be economically advantageous to use machines if certain conditions are met. **Economies of scale** is the observation that average costs of production fall as output increases. This means profits tend to increase with size and large agricultural operations generally outcompete small ones. As a result, between 1950 and 2000, the average farm size in Iowa more than doubled.

Figure 11.5 **Irrigation circles.** The green circles in this aerial photograph from Oregon are obvious evidence of irrigation.

The Green Revolution - Irrigation

Irrigation systems can increase crop growth rates or even enable crops to grow where they could not otherwise be grown. They can also allow productive land to become extremely productive land.

Some negative effects of irrigation systems is it can lead to groundwater depletion or saltwater intrusion into freshwater wells. It can also contribute to soil degradation through *waterlogging* and *salinization*.

The Green Revolution - Irrigation

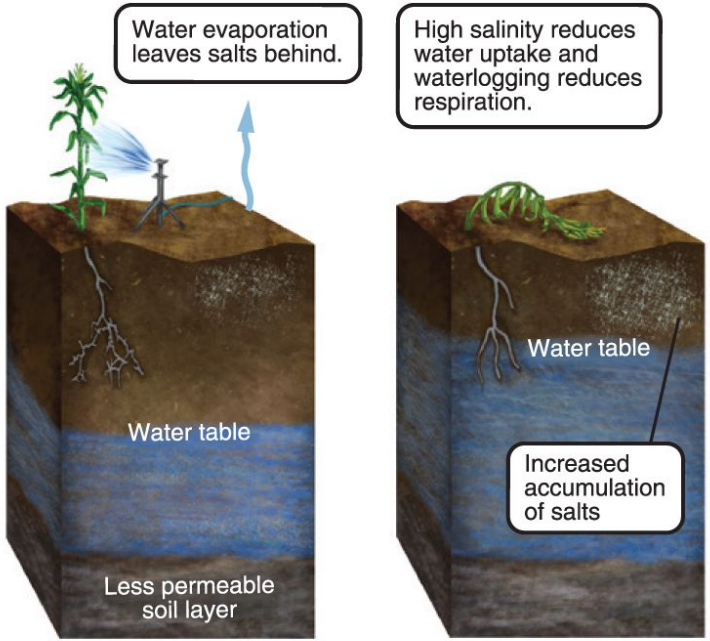


FIGURE 32.3 Irrigation-induced salinization and waterlogging. Over time, irrigation can degrade soil by leaving a layer of highly concentrated salts at the soil surface and waterlogged soil below.

Waterlogging is a form of soil degradation that occurs when soil remains under water for prolonged periods. **Salinization** is a form of soil degradation that occurs when the small amount of salts in irrigation water becomes highly concentrated on the soil surface through evaporation.

The Green Revolution - Fertilizers

Organic matter and nutrients are removed from the soil during crop growth. Fertilizers are used to remedy this effect. The two types of fertilizers used are *organic* and *synthetic*.

Organic fertilizers are composed of organic matter from plants and animals. Typically, they are made up of animal manure and crop residues that have been allowed to decompose.

The Green Revolution - Fertilizers

Synthetic fertilizers, or **inorganic fertilizers**, are produced commercially, normally with the use of fossil fuels. Nitrogen fertilizers are often produced by combusting natural gas, which allows nitrogen from the atmosphere to be fixed and captured in fertilizer. These fertilizers are highly concentrated.

The Green Revolution - Synthetic Fertilizers

Advantages

- Easy application
- Can target specific nutrient needs of a crop or soil
- Easily absorbed by plants

Disadvantages

- Uses large quantities of fossil fuels for production
- Producing nitrogen fertilizer is energy-intensive
- More likely to be carried by runoff into adjacent waterways & aquifers
- Do not add organic matter into the soil

The Green Revolution - Monocropping

Advantages

- Large expanses of land to be planted and harvested at the same time
- With large machinery, the harvest can be done quickly and efficiently
- Application of uniform fertilizers if needed

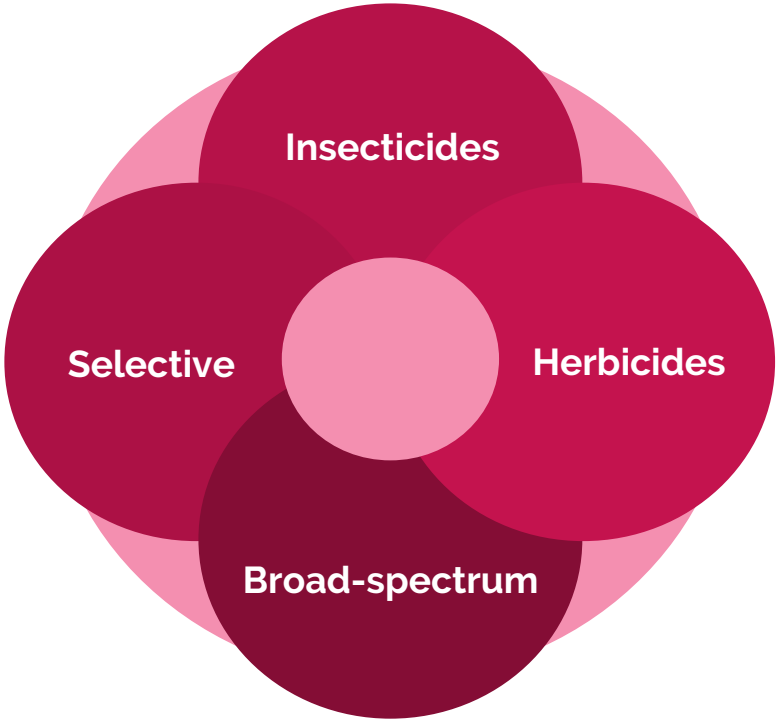
Disadvantages

- Can cause soil erosion
- Makes crops more vulnerable to attack by pests
- May allow pests to experience exponential growth
- Loss of habitat for natural pest predators

Monocropping is an agricultural method that utilizes large planting of a single species or variety. Monocropping is the dominant agricultural practice in the United States and the most common crops are corn, soybean, wheat, and cotton.

The Green Revolution - Pesticides

Pesticides are substances, either natural or synthetic, that kills or controls organisms that people consider pests. The United States accounts for ⅕ of worldwide pesticide use. The categories of pesticides include *insecticides*, *herbicides*, *broad-spectrum pesticide*, and *selective pesticide*.



The Green Revolution - Pesticides

Insecticides target species of insects and other invertebrates that consume crops, while **herbicides** target plant species that compete with crops. **Broad-spectrum pesticides** kill many different types of pests while **selective pesticides** or **narrow-spectrum pesticides** target a narrow range of organisms.

The Green Revolution - Pesticides

Persistent pesticides are pesticides that remain in the environment for a long time. E.g. DDT

Nonpersistent pesticides are pesticides that break down rapidly, usually in weeks or months.

Pesticide resistance is a trait possessed by certain individuals that are exposed to a pesticide and survive.

Pesticide treadmill is a cycle of pesticide development, followed by pest resistance, followed by new pesticide development.

The Green Revolution - Pesticides

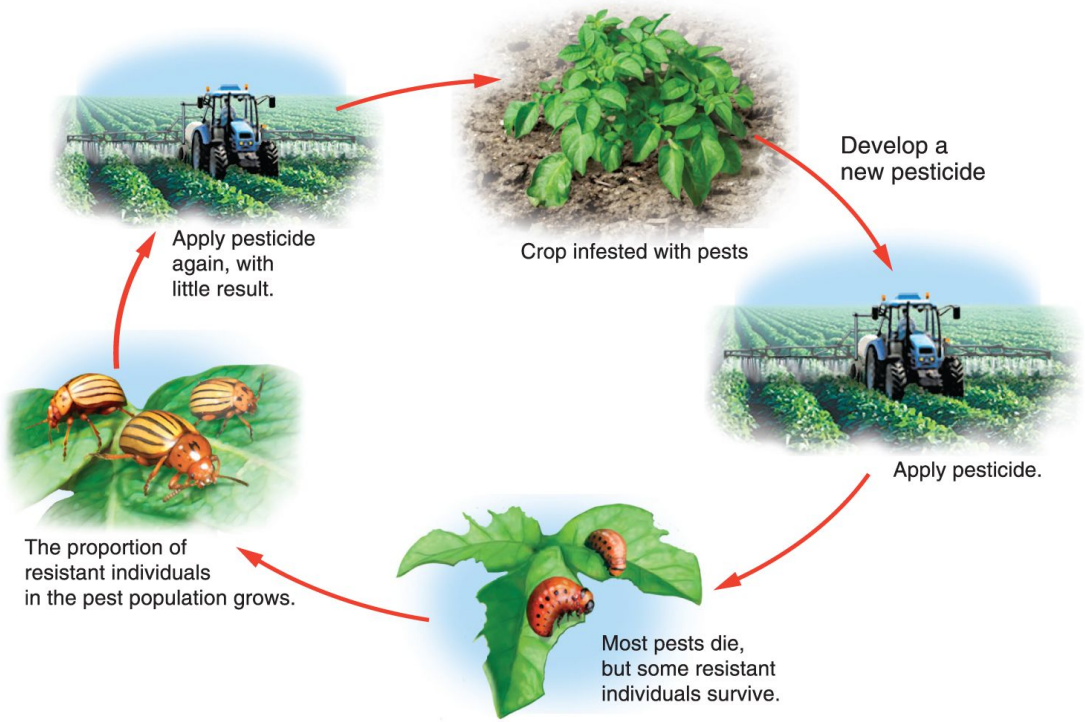


FIGURE 32.6 The pesticide treadmill. Over time, pest populations evolve resistance to pesticides, which requires farmers to use higher doses or to develop new pesticides.

The Green Revolution - Pesticides

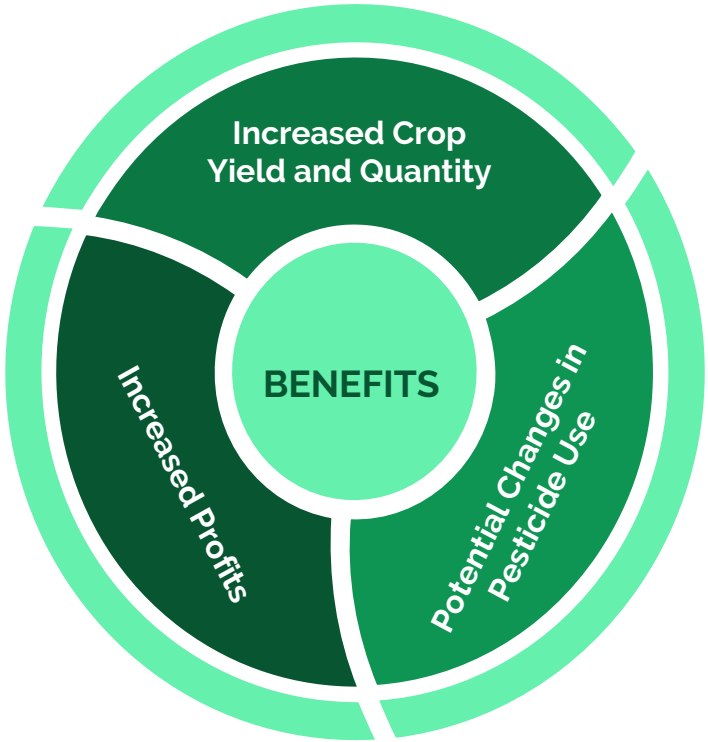
Advantages

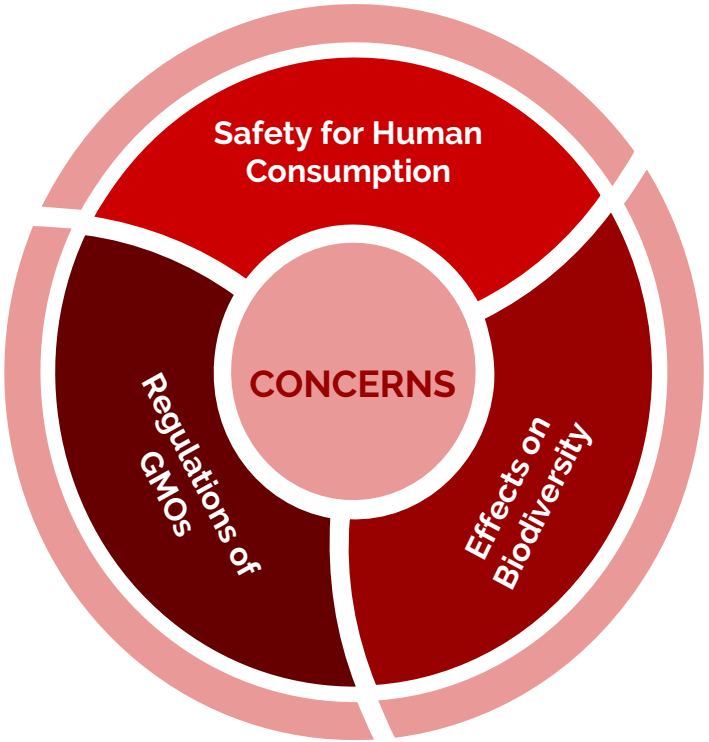
- Allows farmers to quickly and easily respond to an infestation of pests
- Prevents crop damage
- Results in greater crop yield

Disadvantages

- Injure/kill more than the intended targets
- Pest populations may evolve resistance over time
- Chemical pesticides can runoff into surrounding surface waters and pollute groundwater

Genetic Engineering





Genetic Engineering - Benefits

Genetic engineering can increase food production in multiple ways. It can create strains of organisms that are resistant to pests and harsh environmental conditions such as drought or high salinity. Recently, scientists have genetically engineered plants produce essential nutrients for humans.

In addition to plants, some projects are underway to create genetically modified animals, such as salmon that grows to its full size in half the time.

Figure 11.10 White rice and golden rice. (a) Crop scientists have inserted a gene that produces vitamin A into white rice. (b) The resulting genetically modified rice is called golden rice.

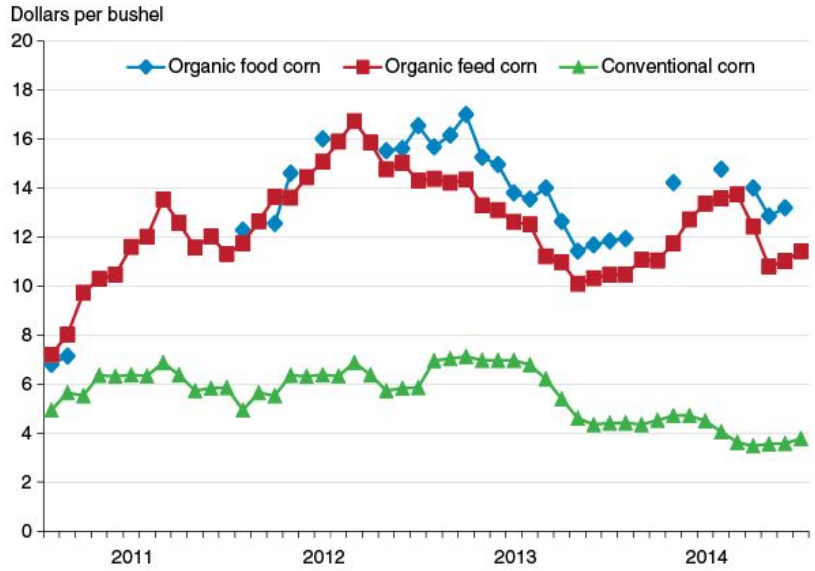
Genetic Engineering - Benefits

Genetic engineering can be used to produce crops with a pesticide in its DNA. There is a “Roundup Ready” gene that allows growers to spray the herbicide on their fields to control the growth of weeds without harming the crop plants. These genes are widely used in corn, soybean, and cotton plants and are referred to as herbicide tolerant, or HT.

There is also an insecticidal gene known as Bt that has been inserted into the genetic material of corn allowing it to be resistant to pests such as the bollworm and lepidopteran.

Genetic Engineering - Benefits

The monthly average price received for organic feed-grade corn was $6.82 higher than for conventional corn during 2011-2014



Source: USDA, Economic Research Service calculations from USDA, Agricultural Marketing Service organic price data and USDA, National Agricultural Statistics Service conventional price data.

GMO seed crops can increase farm profits in two ways. GMO crops do cost more to purchase, however, the reduce pesticide use, which reduces total cost significantly.

GMO crops also produce greater yields which lead to higher incomes for farmers and lower food prices for consumers.

Genetic Engineering - Concerns

Industrial agriculture relies more heavily on genetically modified crops each year. In 2017, 92 percent of the corn, 94 percent of the soybeans, and 96 percent of the cotton planted in the United States came from genetically modified seeds.

Some people are concerned that the ingestion of genetically modified foods may harmful to humans, although so far there is little evidence to support these concerns. Researchers are studying the possibility that GMOs may cause allergic reactions when people eat a food containing genes transferred from another food to which they are allergic.

Genetic Engineering - Concerns

There is also concern that if genetically modified crops breed with their wild relatives then the newly added genes will spread to the wild plants. This could alter or even eliminate natural plant varieties. It’s possible that beneficial traits could be lost.

Genetic Engineering - Concerns

The National Bioengineered Food Disclosure Standard, or the GMO labeling law, was passed in 2016 and signed by President Barack Obama. Currently, the USDA is in the process of implementing the law, which requires disclosure and labeling if a food contains a GMO product.

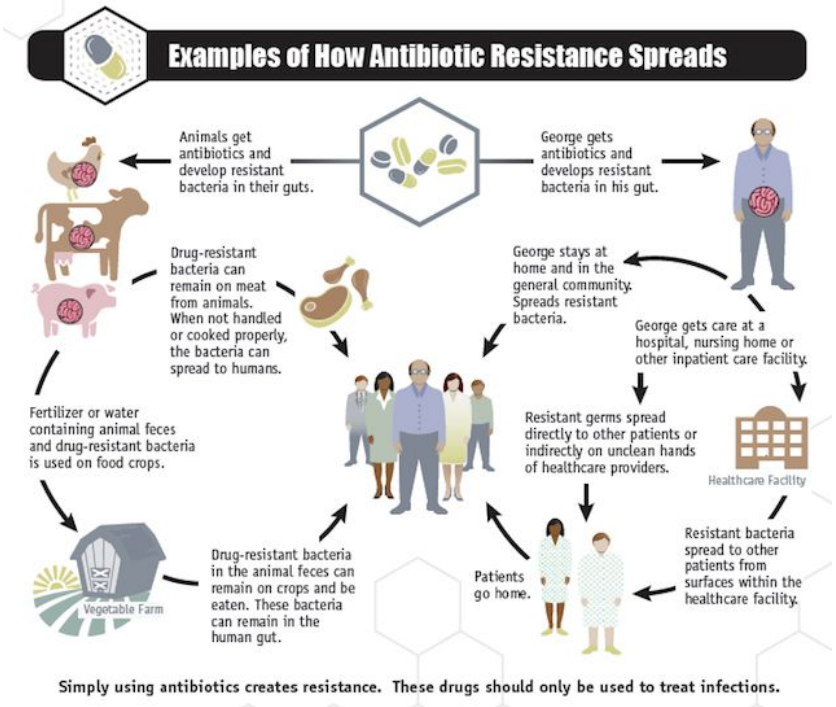
Note that this law does **not** prevent the use of GMOs. Many European countries, such as France, Germany, an Italy, ban almost all GMOs.

Farming Meat & Fish

According to the U.S. Department of Agriculture, in 2016 roughly 150 million animals were slaughtered for beef, prok, and lamb, along with billions of chickens, turkeys, and ducks. Many of these animals were raised in feedlots, or **concentrated animal feeding operations (CAFOs)**, which is a large indoor or outdoor structure designed for maximum output.

Farming Meat & Fish

High-density farming has many environmental and health consequences. Evidence shows that antibiotics given to confined animals contribute to increased antibiotic-resistant strains of microorganisms. An average CAFO produces over 2,000 tons of manure annually, which can cause runoff and pollute groundwater.



Farming Meat & Fish

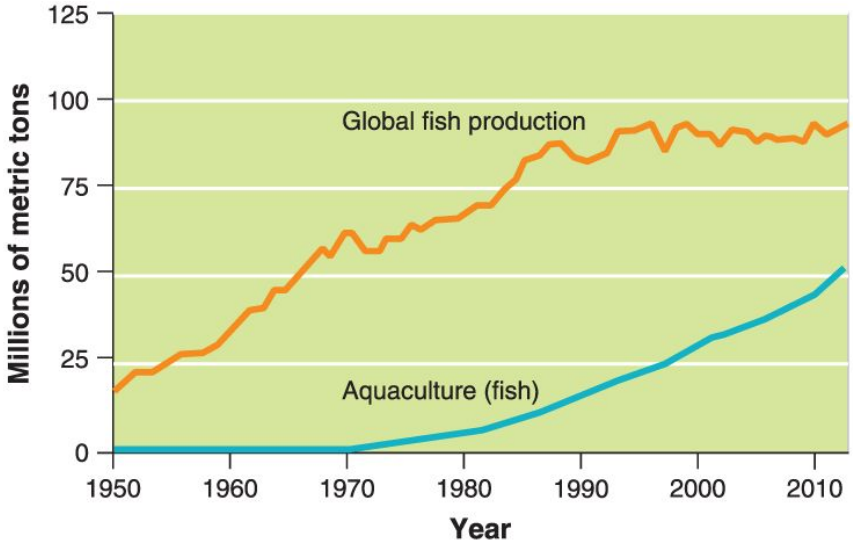
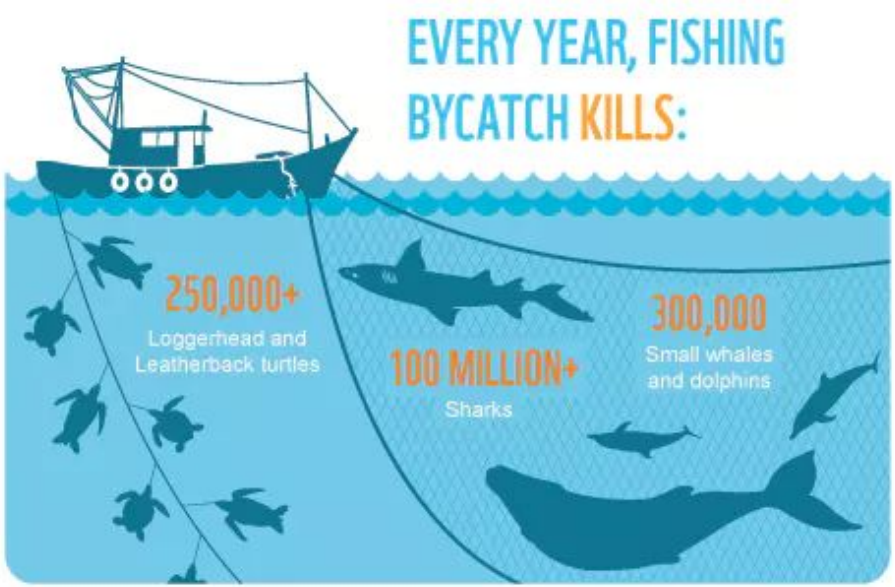


FIGURE 32.9 Global fish production Global fish production has increased by more than 30 percent since 1980, primarily as a result of the large increase in aquaculture. The graph shows data for aquaculture-raised fish (blue) and wild-caught fish production (orange).

Fish is the third major source of food for humans, after grains and meat. The global fish production has increased over 30 percent since 1980.

Aquaculture is the farming of aquatic organisms such as fish, shellfish and seaweeds. A **fishery** is a commercially harvestable population of fish within a particular ecological region.

Farming Meat & Fish



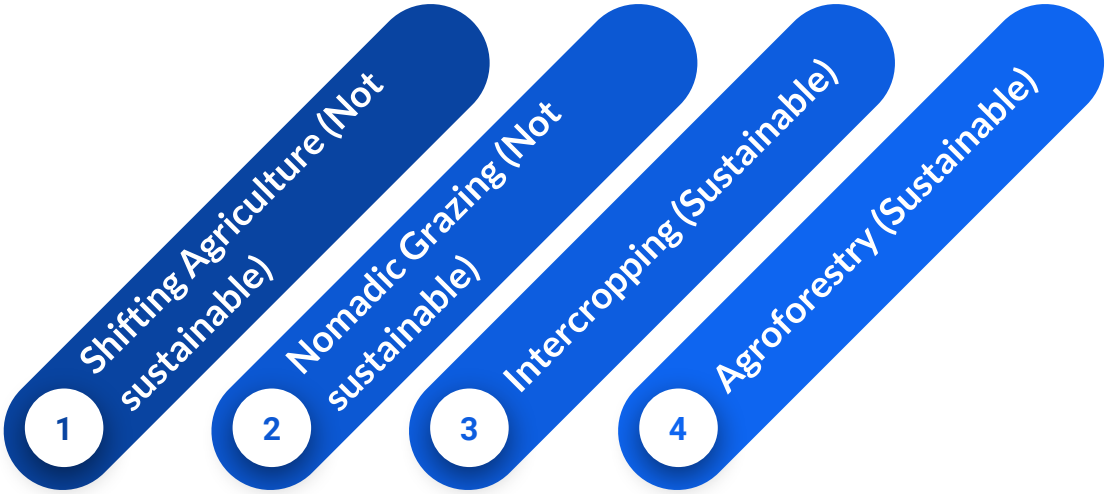
Note that fishing is highly susceptible for tragedy of the commons. A study in 2006 found that 30 percent of fisheries worldwide had experienced a 90 percent or more decline in fish populations. A decline of 90 percent or more is known as a **fish collapse**. One issue that leads to this is using nets which don't target specific species. This leads to **bycatch**, or the unintentional catch of nontarget species while fishing. Another reason is fish travel through international waters which makes it difficult for countries to manage catching outside their domain.

Module 33: Alternatives to Industrial Farming Methods

After this module you will be able to……

1) Describe alternatives to conventional farming methods
2) Explain alternative techniques used in farming animals and in fishing and aquaculture

Alternatives to Farming



Industrial agriculture has been so successful and widespread that it has become known as conventional agriculture. In developing nations small-scale farming is common. Traditional farming methods that differ from those of industrial agriculture include *shifting agriculture*, *nomadic grazing*, *intercropping*, and *agroforestry*.

Shifting Agriculture

Shifting agriculture is an agriculture method in which land is cleared and used for a few years until the soil is depleted of nutrients. Usually, the land is prepared by clearing and burning of a forests prior to planting seeds.

A consequence of this is **soil compaction**, which is a process where repeated trampling by humans, machinery, or animals causes a compaction of soil and a reduction in pore space. This ultimately leads to the an increase in CO and CO_2 in the atmosphere due to oxidation.

Shifting Agriculture

Desertification is the transformation of arable, productive land to desert or unproductive land due to climate change or destructive land use. Today, most of this occurs in Africa where parts of the Sahara are expanding at a rate of up to 50 km per year.

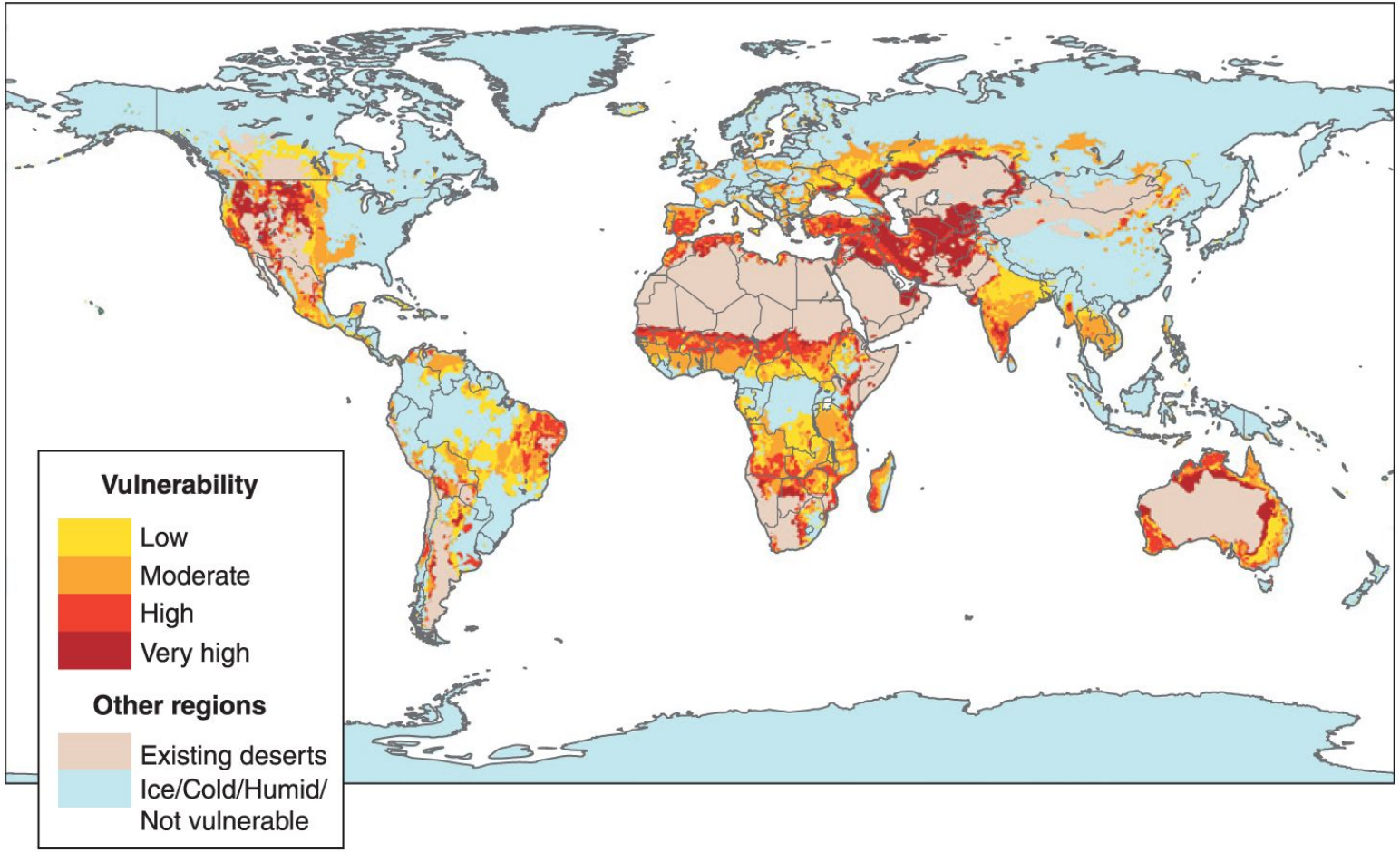


FIGURE 33.2 Vulnerability to desertification. Certain regions of the world are much more vulnerable to desertification than others.

Nomadic Grazing

The only sustainable way for people to use soil types with very low productivity is **nomadic grazing**, which is the feeding of herds of animals by moving them to seasonally productive feeding grounds, often over long distances. This allows the vegetation to regenerate from grazing animals.

Both shifting agriculture and nomadic grazing work well with low population densities, but become less sustainable as populations increase.

Sustainable Agriculture

Sustainable agriculture is agriculture that fulfills the need for food and fiber while enhancing the quality of the soil, minimizing the use of nonrenewable resources, and allowing economic viability for the farmer. Some methods to help promote sustainable agriculture are *intercropping*, *crop rotation*, *agroforestry*, and *contour plowing*.

Sustainable Agriculture

Intercropping is an agricultural method in which two or more crop species are planted in the same field at the same time to promote a synergistic interaction. E.g. corn, which requires a great deal of nitrogen, can be planted alongside peas, a nitrogen-fixation crop.

Crop rotation is a technique in which crop species in a field are rotated from season to season, which can achieve the same effect as intercropping.

Sustainable Agriculture

Agroforestry is an agriculture technique in which trees and vegetables are intercropped. This allows vegetation of different heights to act as windbreaks and catch soil that might otherwise be blown away, greatly reducing soil erosion.

Sustainable Agriculture

Contour plowing is a technique in which plowing and harvesting are done parallel to the topographic contours of the land. This method helps prevent erosion by water while still allowing for the practical advantages of plowing.

(a)

(c)

(b)

FIGURE 33.3 Sustainable farming methods. A variety of farming methods can be used to improve agricultural yield and retain soil and nutrients, including (a) intercropping such as this corn grown in a peach orchard in the state of Washington, (b) contour plowing, such as this farm in Iowa growing alfalfa and corn, and (c) agroforestry such as this shade-grown coffee in Mexico.

No-Till Agriculture

Perennial plants live for multiple years and there is usually no need to disturb the soil. In contrast, **annual plants**, such as wheat and corn, live only one season and must be replanted each year. These plants require plowing and tilling, or turning the soil upside down and pushing crop residues under the topsoil. This leads to oxidation of organic matter, which reduces the total amount of organic matter content in the soil, ultimately leading to an increase of CO_2 in the atmosphere. The next slide shows areas of severe soil degradation.

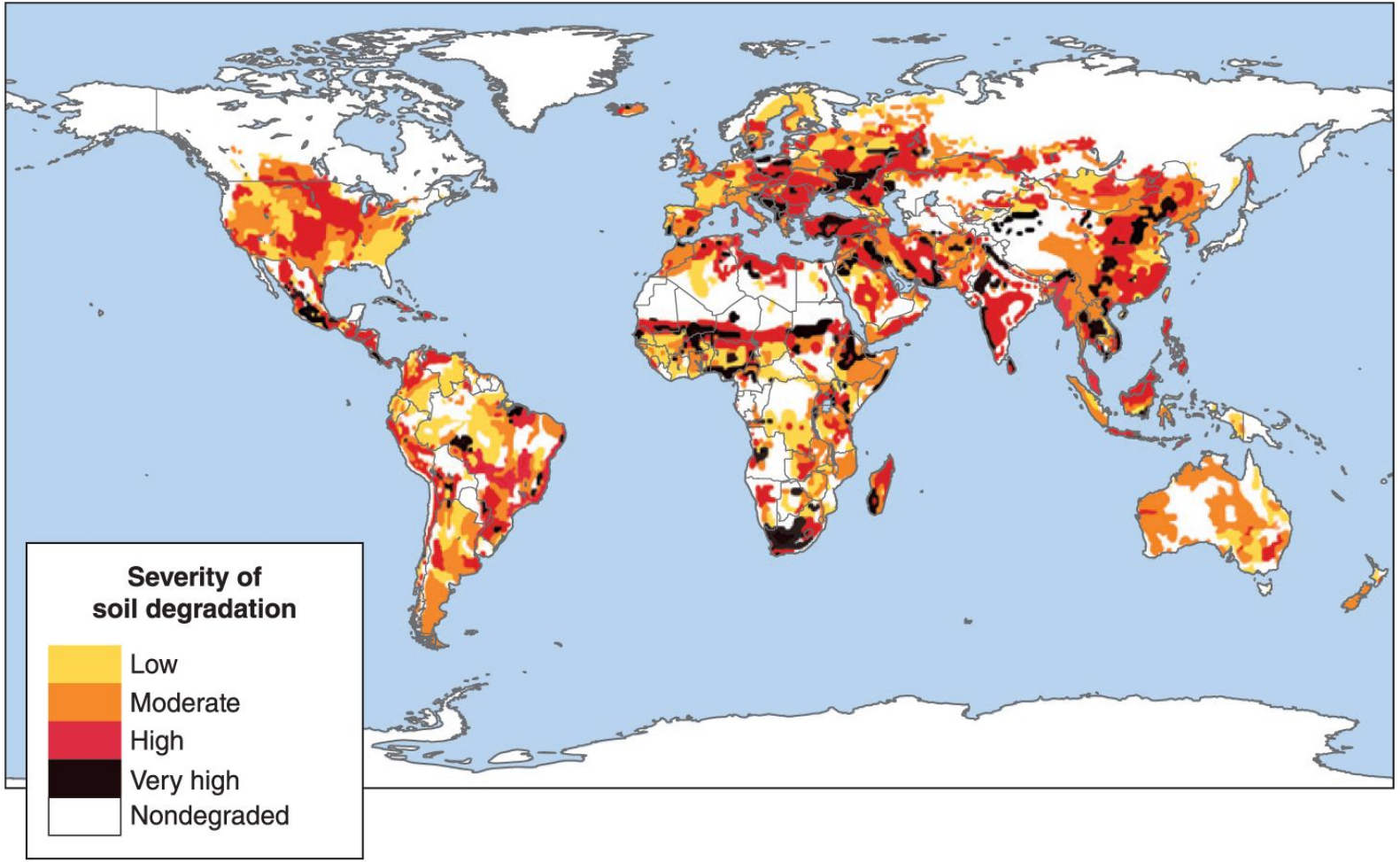
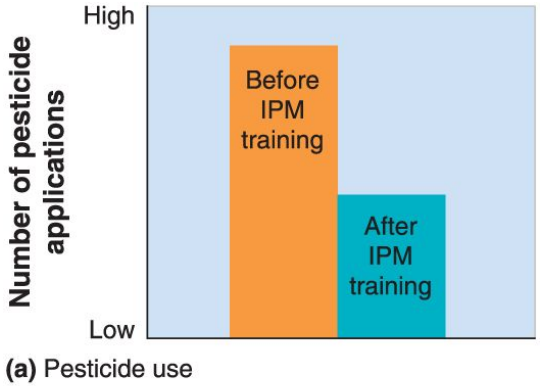


FIGURE 33.4 Global distribution of soil degradation. Soil degradation is a global problem caused by overgrazing and deforestation as well as agricultural mismanagement.

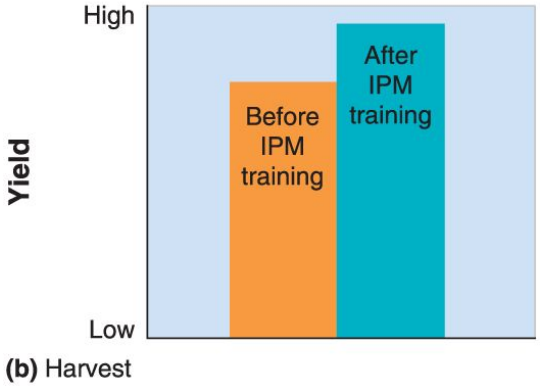
No-Till Agriculture

FIGURE 33.5 No-till agriculture. Rows of soybeans emerge between the residues of a corn crop left over from the previous season.

This leads us to **no-till agriculture**, or a method in which farmers do not turn the soil between seasons as a means of reducing topsoil erosion. This type of agriculture is designed to avoid the soil degradation that comes with conventional agricultural techniques. Farmers using this method leave crop residues in the field between seasons which allow the roots to hold the soil in place. This reduces both wind and water erosion, as well as CO_2 emissions.



(a) Pesticide use

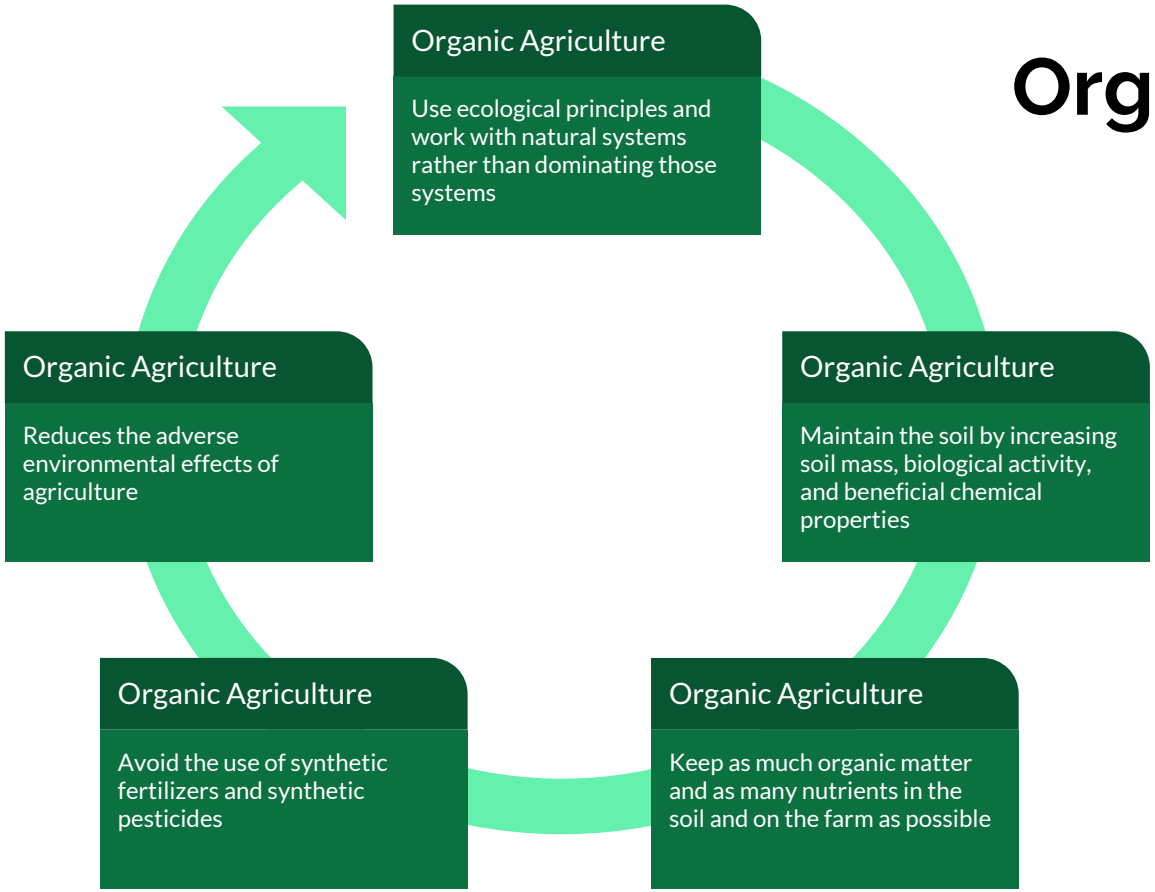


(b) Harvest

Integrated Pest Management

Integrated Pest Management (IPM) is an agricultural practice that uses a variety of techniques designed to minimize pesticide inputs. These techniques include crop rotation and intercropping, the use of pest-resistant crop varieties, the creation of habitats for predators of pests, and limited use of pesticides.

Organic Agriculture



Organic agriculture is the production of crops in a way that sustains or improves the soil, without the use of synthetic pesticides or fertilizers. Organic agriculture follows several basic principles.

Sustainable Fishing

Overharvesting of fish has lead to a decrease of fish in many fisheries. The northwestern Atlantic fisheries experienced a severe decline of fish by the early 1990's and had to close most operations. This led to the U.S. Congress passing the Sustainable Fisheries Act in 1996, which shifted fisheries management from a focus on economic sustainability to an approach that increasingly stressed conservation and the sustainability of species.

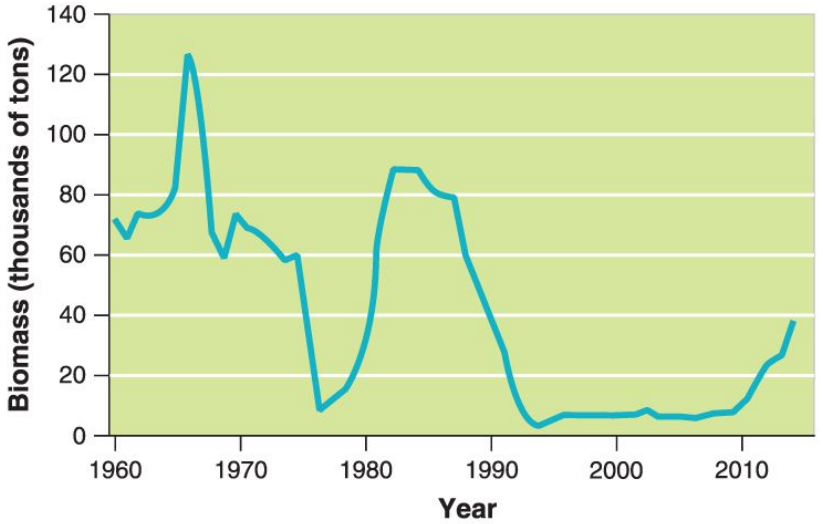


FIGURE 33.9 Fishery collapse in the northwestern Atlantic Ocean. Cod biomass in the Grand Bank, Northwest Atlantic Ocean. A decline beginning in 1985 lasted through 2010. Since then, these fisheries have been recovering.

Sustainable Fishing

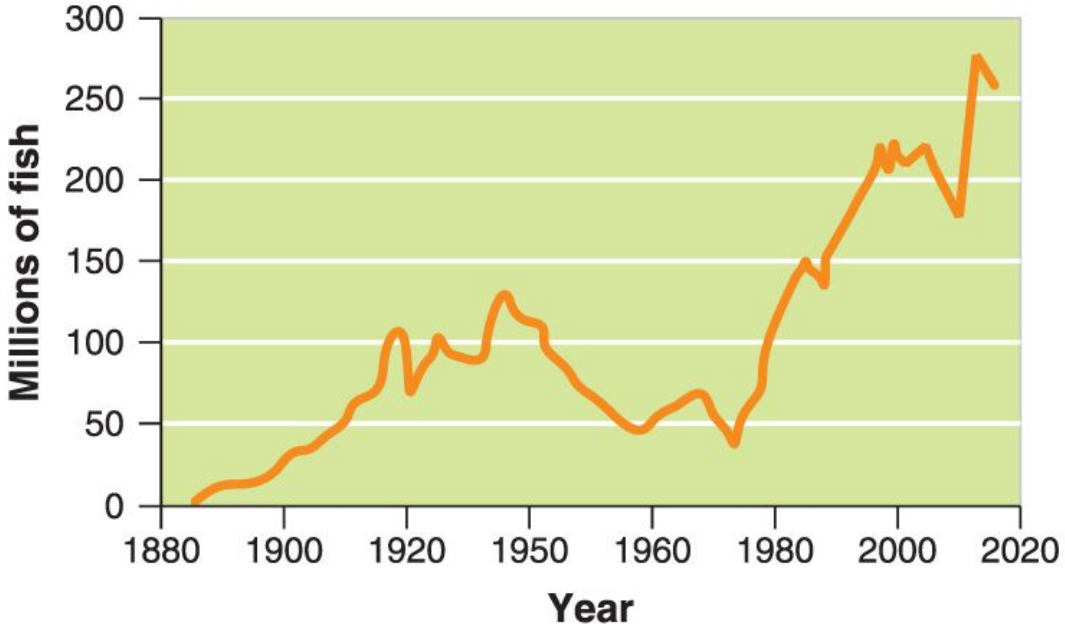


FIGURE 33.10 Commercial salmon harvest in the Alaska fishery. After a peak harvest in 1940, overfishing led to a decline in the number of fish caught. In 1973, fishery managers introduced a system of individual transferable quotas. By 1980, the fishery had rebounded.

In 1973, fishery managers introduced a system of **individual transferable quotas (ITQs)**, a fishery management program in which individual fishers are given a total allowable catch of fish in a season that they can either catch or sell.

Aquaculture

FIGURE 33.11 A salmon farming operation in Chile. Uneaten food and waste released from salmon farms can cause significant nutrient input into natural marine ecosystems.

Aquaculture involves constructing an aquatic ecosystem by stocking the organisms, feeding them, and protecting them from diseases and predators. It may also require providing them with food and antibiotics. Most of the catfish, shrimp, and salmon eaten in the United States are produced by aquaculture.