Chapter 11: Producing Enough Food for the World: How Agriculture
Can We Feed the World?
Can We Feed the World?

• To answer this we must understand how crops grow and how productive they can be.
Can We Feed the World?

• To answer this we must understand how crops grow and how productive they can be.
• If we do feed the world, is it sustainable?
  – Regions farmed for thousands of years
  – Farming changed local ecosystems
  – Nomadic people would farm an area until it became depauperate before moving on to leave the land “fallow”
Can We Feed the World?
Can We Feed the World?

- History of agriculture is a series of human attempts to overcome environmental limitations and problems.
Can We Feed the World?

• History of agriculture is a series of human attempts to overcome environmental limitations and problems.
  – Each solution creates new problems
  – Should expect some side effects
  – Multiple pressures on agricultural land
Can We Feed the World?
Can We Feed the World?

• Large percentage of world’s land area is agricultural
Can We Feed the World?

- Large percentage of world’s land area is agricultural
  - 38% of total land area (excluding Antarctica)
Can We Feed the World?

• Large percentage of world’s land area is agricultural
  – 38% of total land area (excluding Antarctica)
  – Percentage varies by continent
    • 22% in Europe
    • 57% in Australia
    • 44% in US
Can We Feed the World?
Can We Feed the World?

• As population grows, the production of agriculture must grow.
Can We Feed the World?

- As population grows, the production of agriculture must grow.
  - Food supply is already inadequate for some peoples
Can We Feed the World?

- As population grows, the production of agriculture must grow.
  - Food supply is already inadequate for some peoples
  - Marginal land will be put into production to make food available
Can We Feed the World?

• As population grows, the production of agriculture must grow.
  – Food supply is already inadequate for some peoples
  – Marginal land will be put into production to make food available

• Food supply is also influenced by social disruptions and social attitudes (politics).
Can We Feed the World?
Can We Feed the World?

- The key to food production in the future
Can We Feed the World?

• The key to food production in the future
  – Increased production per unit area
    • Requires increased use of water, fertilizers, and pesticides
  • OR implementation of ecological principles in the use of Organic/BioDynamic farming
Can We Feed the World?

• The key to food production in the future
  – Increased production per unit area
    • Requires increased use of water, fertilizers, and pesticides
  • OR implementation of ecological principles in the use of Organic/BioDynamic farming
    – Utilizing marginal lands
Can We Feed the World?

• The key to food production in the future
  – Increased production per unit area
    • Requires increased use of water, fertilizers, and pesticides
  • OR implementation of ecological principles in the use of Organic/BioDynamic farming
    – Utilizing marginal lands
    – As increased production is demanded there will be increased in environmental degradation
How We Starve
How We Starve

- People “starve” in two ways
How We Starve

• People “starve” in two ways
  – Undernourishment- lack of sufficient calories in available food. One has little or no ability to move or work and eventually dies from lack of energy.
How We Starve

• People “starve” in two ways
  – Undernourishment- lack of sufficient calories in available food. One has little or no ability to move or work and eventually dies from lack of energy.
  – Malnourishment- lack of specific chemical components of food, such as protein, vitamins, or other essential chemical elements.
How We Starve
How We Starve

• Undernourishment manifests as famine
  – Obvious, dramatic and fast acting
How We Starve

- Undernourishment manifests as famine
  - Obvious, dramatic and fast acting
- Malnourishment is long-term and insidious
  - May not dies out right but suffer impairments
How We Starve
How We Starve

• Major problem of undernourishment
How We Starve

- Major problem of undernourishment
  - Marasmus – progressive emaciation caused by lack of protein and calories
How We Starve

• Major problem of undernourishment
  – Marasmus – progressive emaciation caused by lack of protein and calories
  – Kwashiorkor - a lack of sufficient protein in the diet
How We Starve

• Major problem of undernourishment
  – Marasmus – progressive emaciation caused by lack of protein and calories
  – Kwashiorkor - a lack of sufficient protein in the diet
  – Chronic hunger - enough food to stay alive but can not live satisfactory or productive lives
How We Starve

• Major problem of undernourishment
  – Marasmus – progressive emaciation caused by lack of protein and calories
  – Kwashiorkor - a lack of sufficient protein in the diet
  – Chronic hunger - enough food to stay alive but can not live satisfactory or productive lives

• World food production must provide adequate nutritional quality as well as quantity. Is access to quality food a basic human right? (like clean air and clean water?)
How We Starve
How We Starve

• Food emergencies affected 34 countries worldwide at the end of 20th century
  – Africa has the most acute food shortages
  – Food distribution major problem
  – World food aid does not meet all the caloric need of people
How We Starve

• Food emergencies affected 34 countries worldwide at the end of 20th century
  – Africa has the most acute food shortages
  – Food distribution major problem
  – World food aid does not meet all the caloric need of people

• Best solution is to increase local production
Percentage of population undernourished (1997–1999)

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 2.5</td>
</tr>
<tr>
<td>2</td>
<td>2.5 – 5</td>
</tr>
<tr>
<td>3</td>
<td>5 – 20</td>
</tr>
<tr>
<td>4</td>
<td>20 – 35</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 35</td>
</tr>
</tbody>
</table>
What We Eat and What We Grow
What We Eat and What We Grow

• Of Earth’s ½ million plant species
What We Eat and What We Grow

- Of Earth’s $\frac{1}{2}$ million plant species
  - 3,000 agricultural crops
What We Eat and What We Grow

• Of Earth’s ½ million plant species
  – 3,000 agricultural crops
  – 150 species cultivated on large scale
What We Eat and What We Grow

• Of Earth’s ½ million plant species
  – 3,000 agricultural crops
  – 150 species cultivated on large scale
  – 14 crop species provide most of the food consumed in the world
What We Eat and What We Grow

• Of Earth’s ½ million plant species
  – 3,000 agricultural crops
  – 150 species cultivated on large scale
  – 14 crop species provide most of the food consumed in the world
  – 6 plants provide 80% of the total calories for ALL humanity
Crops
Crops

- Forage - crops grown for domestic animals
  - 14 million acres of alfalfa in the US
Crops

- **Forage** - crops grown for domestic animals
  - 14 million acres of alfalfa in the US

- **Domestic animals include**
  - 14 billion chickens
  - 1.3 million cattle
  - ~1 billion each sheep, ducks and pigs
  - 700 million goats
  - 160 million water buffalo
  - 18 million camels
Crops
Crops

• Rangeland - provides food for grazing and browsing animals w/o plowing and planting.
Crops

• Rangeland - provides food for grazing and browsing animals w/o plowing and planting.
• Pasture- is plowed, planted and harvested to provide forage. It is often irrigated for maximum productivity.
Crops

- Rangeland - provides food for grazing and browsing animals w/o plowing and planting.
- Pasture- is plowed, planted and harvested to provide forage. It is often irrigated for maximum productivity
- World market for small grain crops (rice, wheat, soybeans).
  - Production has been flat since 1996
Aquaculture
Aquaculture

• Most marine and freshwater food is obtained by hunting.
  – Sustainability – this is NOT sustainable
Aquaculture

• Most marine and freshwater food is obtained by hunting.
  – Sustainability – this is NOT sustainable

• Aquaculture- the farming of food in aquatic habitats
  – Important protein source for many people
Aquaculture
Aquaculture

- Extremely productive on a per-area basis
Aquaculture

- Extremely productive on a per-area basis
  - Flowing water brings food into the pond from outside
Aquaculture

• Extremely productive on a per-area basis
  – Flowing water brings food into the pond from outside
  – Can exploit multiple niches in the pond
Aquaculture

- Extremely productive on a per-area basis
  - Flowing water brings food into the pond from outside
  - Can exploit multiple niches in the pond
  - May be able to utilize waste products (treated sewage)
Aquaculture

• Extremely productive on a per-area basis
  – Flowing water brings food into the pond from outside
  – Can exploit multiple niches in the pond
  – May be able to utilize waste products (treated sewage)

• Mariculture - the farming of ocean fish.
  – Oysters and mussel production has been on the rise and is evident locally in Carlsbad on offshore in Ensenada
An Ecological Perspective on Agriculture

• Farming creates novel ecological conditions
  – Agroecosystem
  – Differ from natural systems in six ways
Agroecosystem
(conventional ag)
Agroecosystem
(conventional ag)

• 1. In farming we try to stop ecological succession and keep the agroecosystem in an early-successional state.
Agroecosystem (conventional ag)

1. In farming we try to stop ecological succession and keep the agroecosystem in an early-successional state.

2. Monoculture - large areas planted with a single species
   - Counteracted by crop rotation to avoid pest problems and soil infertility
Agroecosystem (conventional ag)

1. In farming we try to stop ecological succession and keep the agroecosystem in an early-successional state.
2. Monoculture- large areas planted with a single species
   - Counteracted by crop rotation to avoid pest problems and soil infertility
3. Crops planted in neat rows, which makes life easy for pests.
Agroecosystem (conventional ag)
Agroecosystem (conventional ag)

• 4. Farming greatly simplifies biological diversity and food chains.
Agroecosystem (conventional ag)

• 4. Farming greatly simplifies biological diversity and food chains.

• 5. Plowing is unlike any natural soil disturbance.
  – Nothing in nature repeatedly and regularly turns over the soil to a specific depth.
Agroecosystem (conventional ag)

- 4. Farming greatly simplifies biological diversity and food chains.
- 5. Plowing is unlike any natural soil disturbance.
  - Nothing in nature repeatedly and regularly turns over the soil to a specific depth.
- 6. Genetic modification of crops
Limiting Factors
Limiting Factors

- High-quality agricultural soil has:
Limiting Factors

• High-quality agricultural soil has:
  – All the chemical elements required for plants
Limiting Factors

- High-quality agricultural soil has:
  - All the chemical elements required for plants
  - A physical structure that lets air and water move freely
Limiting Factors

• High-quality agricultural soil has:
  – All the chemical elements required for plants
  – A physical structure that lets air and water move freely
  – Retains water well
Limiting Factors

• High-quality agricultural soil has:
  – All the chemical elements required for plants
  – A physical structure that lets air and water move freely
  – Retains water well
  – Mixture of soil particles with various sizes
Limiting Factors
Limiting Factors

• Liebig’s Law
Limiting Factors

• Liebig’s Law
  – Single factor determines the growth and therefore the presence of a species
Limiting Factors

• Liebig’s Law
  – Single factor determines the growth and therefore the presence of a species
  – Growth of a plant is affected by one limiting factor (plants can only grow as much as they have the most limiting nutrient present)
  – 20 chemical elements are required plant nutrients
  – Macro- and micro- nutrients
• Two elements may have a synergistic effect
  – A change in the availability of one resource affects the response of an organism to some other resource.
Two elements may have a synergistic effect

- A change in the availability of one resource affects the response of an organism to some other resource.

Nutrients may become toxic when levels are too high (fertilizer burns and salting out from long term irrigation with high salt content water)
• Two elements may have a synergistic effect
  – A change in the availability of one resource affects the response of an organism to some other resource.

• Nutrients may become toxic when levels are too high (fertilizer burns and salting out from long term irrigation with high salt content water)

• Older soils more likely to lack trace elements
The Future of Agriculture
The Future of Agriculture

- Three major technological approaches to agriculture
The Future of Agriculture

• Three major technological approaches to agriculture
  – 1. Modern mechanized agriculture
The Future of Agriculture

• Three major technological approaches to agriculture
  – 1. Modern mechanized agriculture
  – 2. Resource-based agriculture
    • Organic food production
The Future of Agriculture

• Three major technological approaches to agriculture
  – 1. Modern mechanized agriculture
  – 2. Resource- based agriculture
    • Organic food production
  – 3. Bioengineering
Demand-based agriculture
Resource-based agriculture

- Contour plowing
- Introduction of natural enemies of pests
- Chemical herbicides to control weeds; otherwise, limited use of chemical pesticides
- Drip irrigation
- No-till agriculture
An organic farm
History of Agriculture
History of Agriculture

• 1. Resource-based agriculture and what we now call organic agriculture were introduced about 10,000 years ago.
History of Agriculture

• 1. Resource-based agriculture and what we now call organic agriculture were introduced about 10,000 years ago.

• 2. A shift to mechanized, demand-based agriculture occurred during the Industrial Revolution of the 18th and 19th centuries.
History of Agriculture

• 1. Resource-based agriculture and what we now call organic agriculture were introduced about 10,000 years ago.
• 2. A shift to mechanized, demand-based agriculture occurred during the Industrial Revolution of the 18\textsuperscript{th} and 19\textsuperscript{th} centuries.
• 3. A return to resource-based agriculture began in the 20\textsuperscript{th} century, using new techniques.
History of Agriculture

• 1. Resource-based agriculture and what we now call organic agriculture were introduced about 10,000 years ago.
• 2. A shift to mechanized, demand-based agriculture occurred during the Industrial Revolution of the 18th and 19th centuries.
• 3. A return to resource-based agriculture began in the 20th century, using new techniques.
• 4. Today there is a growing interest in organic agriculture as well as use of genetically engineered crops.
The Green Revolution
The Green Revolution

Name attached to the post WWII programs that have led to the development of:
The Green Revolution

Name attached to the post WWII programs that have led to the development of:

– new strains of crops w/ higher yields
The Green Revolution

Name attached to the post WWII programs that have led to the development of:

– new strains of crops w/ higher yields
– better resistance to disease
The Green Revolution

Name attached to the post WWII programs that have led to the development of:

– new strains of crops w/ higher yields
– better resistance to disease
– or better ability to grow under poor conditions
– Application of large amounts of chemical fertilizers
The Green Revolution

Name attached to the post WWII programs that have led to the development of:
– new strains of crops w/ higher yields
– better resistance to disease
– or better ability to grow under poor conditions
– Application of large amounts of chemical fertilizers

Was made possible by availability of large amounts of petroleum for making chemical fertilizers
Improved Irrigation

- Better irrigation techniques could improve crop yield and reduce overall water use by:
  - Drip irrigation
  - Hydroponics
Organic Farming
Organic Farming

- Organic farming typically considered to have many qualities:
Organic Farming

- Organic farming typically considered to have many qualities:
  - More like nature ecosystem than monoculture
Organic Farming

• Organic farming typically considered to have many qualities:
  – More like nature ecosystem than monoculture
  – Minimizes negative environmental impacts
Organic Farming

• Organic farming typically considered to have many qualities:
  – More like nature ecosystem than monoculture
  – Minimizes negative environmental impacts
  – The food that results does not contain artificial compounds
  – Taste better!!!!
  – Sustainable
  – Doesn’t expose workers to harmful chemicals
Organic Farming

- Organic farming typically considered to have many qualities:
  - More like nature ecosystem than monoculture
  - Minimizes negative environmental impacts
  - The food that results does not contain artificial compounds
  - Taste better!!!!
  - Sustainable
  - Doesn’t expose workers to harmful chemicals

- One of the fastest growing sectors in US ag
POLYCULTURE
POLYCULTURE

• Plant a mixture of crops and/or a broad range of genotypes
POLYCULTURE

• Plant a mixture of crops and/or a broad range of genotypes
  – Gives lower average yearly production but reduces the risk of very low production years.
  – Labor intense
  – Requires better education in ecology and Integrated Pest Management (IPM)
Eating Lower on the Food Chain
Eating Lower on the Food Chain

• Some people believe it is ecologically unsound to use domestic animals for food.
  – Eating each step up the food chain leaves much less food to eat per acre as a result of trophic level inefficiencies
Eating Lower on the Food Chain

• Some people believe it is ecologically unsound to use domestic animals for food.
  – Eating each step up the food chain leaves much less food to eat per acre as a result of trophic level inefficiencies

• On the best ag land this hold true, but many rangelands are better suited to livestock production
  – These areas are often hilly or mountainous and therefore susceptible to rapid erosion of their thin soils
Steepest slopes or worst climates: no agriculture

Steep slopes, harsh climates

Moderate slopes, good climate

Tundra

Silviculture

Moderate slopes or land in hostile climate: rangeland

Orchards

Domestic animals

Flatlands: annual crops

Aquaculture

Fish ponds
Eating Lower on the Food Chain
Eating Lower on the Food Chain

- Another problem with the argument is that animals are a major source of protein and minerals for many populations.
Eating Lower on the Food Chain

• Another problem with the argument is that animals are a major source of protein and minerals for many populations.

• Other factors:
Eating Lower on the Food Chain

• Another problem with the argument is that animals are a major source of protein and minerals for many populations.

• Other factors:
  – Animals are still used for plowing (the entire Andean Plateau agriculture is an example)
Eating Lower on the Food Chain

- Another problem with the argument is that animals are a major source of protein and minerals for many populations.
- Other factors:
  - Animals are still used for plowing (the entire Andean Plateau agriculture is an example)
  - Carrying goods
Eating Lower on the Food Chain

• Another problem with the argument is that animals are a major source of protein and minerals for many populations.

• Other factors:
  – Animals are still used for plowing (the entire Andean Plateau agriculture is an example)
  – Carrying goods
  – Wool and leather – source of clothing
Eating Lower on the Food Chain

• Another problem with the argument is that animals are a major source of protein and minerals for many populations.

• Other factors:
  – Animals are still used for plowing (the entire Andean Plateau agriculture is an example)
  – Carrying goods
  – Wool and leather – source of clothing
  – Fuel and fertilizer source (excrement)
  – Eventually these animals can be consumed
Religion

- Hindus do not consume meat in India, but this is for religious/cultural reasons and eating at a lower trophic level is not the issue (this culture/religion represents a HUGE fraction of the entire population of the world)
Genetically Modified Food
Genetically Modified Food

- Scientist have been able to transfer specific genetic characteristics from one species to another
Genetically Modified Food

• Scientist have been able to transfer specific genetic characteristics from one species to another
• Genetic engineering in ag involves several practices
Genetically Modified Food

- Scientist have been able to transfer specific genetic characteristics from one species to another
- Genetic engineering in ag involves several practices
  - Faster and more efficient ways to develop hybrids
  - Introduction of the terminator gene
  - Transfer of genetic properties from widely divergent kinds of life (antifreeze gene in fish to strawberries and tomatoes – is this a good practice?)
Genetically Modified Food
Genetically Modified Food

• Considerable interest in developing crops
  – With entirely new characteristics
    • E.g. nitrogen fixation
  – With tolerance of drought, cold, heat and toxic chemical elements.
Genetically Modified Food

• Considerable interest in developing crops
  – With entirely new characteristics
    • E.g. nitrogen fixation
  – With tolerance of drought, cold, heat and toxic chemical elements.

• Most Genetic engineering of plants to date has involved making them either pest resistant, or herbicide resistant – not making them more productive to provide greater quantities of food to the people of the world.
STOP CONTAMINACIÓN GENÉTICA
GREENPEACE
Climate Change and Agriculture
Climate Change and Agriculture

- Climate change may increase or decrease yield depending on the complex interaction between local weather, evapotranspiration, soil condition, and availability of fresh water
What’s your vision for the future?