No-till agriculture in Iowa

- Repeated plowing and planting damage soil
- No-till farming
  - Benefits the soil
  - Saves time and money
- Other conservation measures:
  - Careful use of fertilizers
  - Preventing erosion
  - Retiring fragile soils
- Production is not lowered
Soil: the foundation for agriculture

- Land devoted to agriculture covers 38% of Earth’s land
- **Agriculture** = practice of raising crops and livestock for human use and consumption.
- **Cropland** = land used to raise plants for human use
- **Rangeland or pasture** = land used for grazing livestock
- **Soil** = a complex plant-supporting system
  - Consists of disintegrated rock, organic matter, water, gases, nutrients, and microorganisms
  - It is a renewable resource that can be depleted
Population and consumption degrade soil

- Feeding the world’s rising human population requires changing our diet or increasing agricultural production
  - But land suitable for farming is running out
  - We must improve the efficiency of food production
  - We must decrease our impact on natural systems
- Mismanaged agriculture turns grasslands into deserts, removes forests, diminishes biodiversity
  - It also pollutes soil, air, and water with chemicals
  - Fertile soil is blown and washed away
Millions of acres of cropland are lost each year

We lose 5–7 million ha (12–17 million acres) of productive cropland each year
Soil degradation has many causes

- Soil degradation: a decline in quality and productivity
- From deforestation, agriculture, overgrazing

*Over the past 50 years, soil degradation has reduced global grain production by 13%*
Agriculture arose 10,000 years ago

- Different cultures independently invented agriculture
- The earliest plant and animal domestication is from the “Fertile Crescent” of the Middle East
  - Wheat, barley, rye, peas, lentils, onions, goats, sheep
Traditional agriculture

- Agriculture allowed people to settle in one place
  - Populations increased
  - Leading to more intensive agriculture

- Traditional agriculture = biologically powered
  - Uses human and animal muscle power
  - Hand tools, simple machines
  - Subsistence agriculture = families produce only enough food for themselves
  - Polyculture = different crops are planted in one field
**Industrialized agriculture**

- **Industrialized agriculture** = uses large-scale mechanization and fossil fuels to boost yields
  - Also uses pesticides, irrigation, and fertilizers
  - **Monoculture** = uniform planting of a single crop

- **Green revolution** = new technology, crop varieties, and farming practices were introduced to developing countries
  - Increased yields and decreased starvation
  - Created new problems and worsened old ones
Soil as a system

- Soil consists of mineral and organic matter, air, and water
  - Dead and living microorganisms
  - Decaying material
  - Bacteria, algae
  - Habitat for earthworms, insects, mammals, reptiles, and amphibians

Since soil is composed of interacting living and nonliving matter, it is considered an ecosystem
Soil formation is a slow process

- **Parent material** = the base geologic material of soil
  - Lava, volcanic ash, rock, dunes
  - **Bedrock** = solid rock comprising the Earth’s crust

- **Weathering** = processes that form soil
  - Described on the next slide

- **Humus** = spongy, fertile material formed by partial decomposition of organic matter
Weathering produces soil

1. Physical weathering (wind, rain, thermal expansion and contraction, water freezing)
2. Chemical weathering (water and gases)
3. Biological weathering (tree roots and lichens)

Parent material (rock) → Smaller particles of parent material
Key processes in soil formation

- Key processes in forming soil: weathering and the accumulation and transformation of organic matter
- They are influenced by the following factors:
  - Climate: soils form faster in warm, wet climates
  - Organisms: plants and decomposers add organic matter
  - Topography: hills and valleys affect exposure to sun, wind, and water
  - Parent material: influences properties of resulting soil
  - Time: soil can take decades to millennia to form
A soil profile consists of horizons

- **Horizon** = each layer of soil
  - Soil can have up to six horizons
- **Soil profile** = the cross-section of soil as a whole
- **Leaching** = dissolved particles move down through horizons
  - Some materials in drinking water are hazardous
- **Topsoil** = inorganic and organic material most nutritive for plants
Soils are characterized in many ways

- Soils are classified by color, texture, structure, and pH
- Soil color = indicates its composition and fertility
  - Black or dark brown = rich in organic matter
  - Pale gray or white = indicates leaching
- Soil texture = determined by the size of particles
  - From smallest to largest: **clay, silt, sand**
    - **Loam** = soil with an even mixture of the three
- Affects how easily air and water travel through the soil
- Influences how easy soil is to cultivate
Soil texture classification

Silty soils with medium-size pores, or loamy soils with mixtures of pore sizes, are best for plant growth and agriculture.
Soil structure and pH

- **Soil structure** = a measure of soil’s “clumpiness”
  - A medium amount of clumpiness is best for plants
  - Repeated tilling compacts soil, decreasing its water-absorbing capabilities

- **Soil pH** = affects a soil’s ability to support plant growth
  - Soils that are too acidic or basic can kill plants
  - pH influences the availability of nutrients for plants
Cation exchange is vital for plant growth

- *Cation exchange* = process that allows plants to gain nutrients
  - Negatively charged soils hold cations (positively charged ions) of calcium, magnesium, and potassium
  - Roots donate hydrogen to soil in exchange for these nutrients

- *Cation exchange capacity* = a soil’s ability to hold cations
  - Cations that don’t leach are more available to plants
  - A useful measure of soil fertility
  - Greatest in fine or organic soils
Regional differences in soils affect agriculture

- In rainforests the nutrients are in plants, not the soil
  - Rain leaches minerals and nutrients, reducing their accessibility to roots
  - Rapid decomposition of leaf litter results in a thin topsoil layer with little humus
- Swidden agriculture = traditionally used in tropical areas
  - After cultivation, a plot is left to regrow into forest
- Temperate prairies have lower rainfall and less nutrient leaching
Differences in regional agriculture

- Swidden agriculture is not sustainable at high population densities.
- Dead plants return nutrients to the soil on the Iowa prairie.
Land degradation and soil conservation

- Human activities are limiting productivity by degrading soils in many areas

- **Land degradation** = a general deterioration of land, decreasing its productivity and biodiversity
  - Erosion, nutrient depletion, water scarcity, salinization, waterlogging, chemical pollution
  - The soil’s structure and pH change, and it loses organic material
Soil conservation
• Land degradation is caused by intensive, unsustainable agriculture
  - Also by deforestation and urban development
• It affects up to one-third of the world’s people
Erosion degrades ecosystems and agriculture

- **Erosion** = removal of material from one place to another
  - By wind or water
- **Deposition** = arrival of eroded material at a new location
- Flowing water deposits nutrient-rich sediment in river valleys and deltas
  - Floodplains are excellent for farming
  - Flood control measures decrease long-term farming productivity
- Erosion occurs faster than soil is formed
  - It also removes valuable topsoil
Soil erodes by several methods

- Erosion occurs through wind and four types of water erosion
  - *Rill* erosion, *gully* erosion, *sheet* erosion and *splash* erosion
  - Water erosion occurs most easily on steep slopes

- Land is made more vulnerable to erosion through:
  - Overcultivating fields through poor planning or excessive tilling
  - Overgrazing rangelands
  - Clearing forests on steep slopes or with large clear-cuts
Erosion removes soil
• Water erosion removes soil from farmlands

-Erosion in the U.S. has declined due to soil conservation measures
Erosion can be prevented

- Erosion can be hard to detect and measure
  - Five tons/acre of soil is only as thick as a penny
- Physical barriers to capture soil can prevent erosion
- Plants prevent soil loss by slowing wind and water flow
  - Roots hold soil in place
  - No-till agriculture leaves plant residue on fields
  - Cover crops protect soil between crop plantings

*Despite conservation measures, the U.S. still loses 5 tons of soil for every ton of grain harvested*
Soil erosion is a global problem

- Humans are the primary cause of erosion

  - It is occurring at unnaturally high rates

  - In Africa, erosion could reduce crop yields by half over the next 40 years

- Conservation farming decreases erosion

  *When added to population growth, some describe agriculture’s future as a crisis situation*
Desertification reduces productivity

- **Desertification** = a loss of more than 10% productivity
  - Erosion, soil compaction
  - Deforestation and overgrazing
  - Drought, salinization, water depletion
  - Climate change
- Most prone areas = arid and semiarid lands (drylands)
Desertification has high costs

- Desertification affects one-third of the planet’s land area
  - In over 100 countries
  - Endangering food supplies of 1 billion people
- It costs tens of billions of dollars each year
  - China loses over $6.5 billion/year from overgrazing
  - 80% of land in Kenya is vulnerable to desertification from overgrazing and deforestation
- Desertification is intensified
  - Degradation forces farmers onto poorer land
  - Farmers reduce fallow periods, so land loses nutrients
The Dust Bowl

- In late 1800 and early 1900, farmers and ranchers:
  - Grew wheat, grazed cattle
  - Removed vegetation

- **Dust Bowl** = 1930s drought + erosion caused “black blizzards” of sand

- Thousands of farmers left their land
  - Relied on governmental help to survive
The Soil Conservation Service (SCS)

- Started in 1935, the Service works with farmers to:
  - Develop conservation plans for farms
  - Assess the land’s resources, problems, opportunities
  - Prepare an integrated plan
  - Work closely with landowners
  - Implement conservation measures

- **Conservation districts** = operate with federal direction, authorization, and funding
  - But are organized by the states
The SCS became the NRCS in 1994

- Districts implement conservation programs
  - Residents plan and set priorities

- Natural Resources Conservation Service (NRCS)
  - Also includes water quality protection and pollution control

*Agricultural extension agents* = agency or university experts who advise and help farmers
International soil conservation efforts

• The SCS and NRCS serve as models for efforts around the world

• A large part of Argentina, Brazil, and Paraguay uses no-till farming
  - Resulting from grassroot farmers’ organizations
  - Helped by agronomists and extension agents

An extension agent helps a farmer grow yucca plants in Colombia, South America
Protecting soil: Crop rotation and Contour farming

- **Crop rotation** = growing different crops from one year to the next
  - Returns nutrients to soil
  - Prevents erosion, reduces pests
  - Wheat or corn and soybeans

- **Contour farming** = plowing perpendicular across a hill
  - Prevents rills and gullies
Protecting soil: terracing and intercropping

- **Terracing** = level platforms cut into steep hillsides
  - This “staircase” often contains water

- **Intercropping** = planting different crops in alternating bands
  - Increases ground cover
  - Replenishes soil
  - Decreases pests and disease
Protecting soil: shelterbelts and reduced tillage

- **Shelterbelts** (*windbreaks*) = rows of trees planted along edges of fields
  - Slows the wind
  - Can be combined with intercropping
- **Conservation tillage** = reduces the amount of tilling
  - Leaves at least 30% of crop residues in the field
  - **No-till** farming disturbs the soil even less
Conservation tillage saves soil

- It increases organic matter and soil biota
  - Reducing erosion and improving soil quality
- Prevents carbon from entering the atmosphere
- Reduces fossil fuel use
- But may increase use of herbicides and fertilizers
Conservation tillage around the world

- 40% of U.S. farmland uses conservation tillage
  - Also used in Brazil, Argentina, Paraguay
- To minimize problems:
  - Use green manure (dead plants as fertilizer)
  - Rotate fields with cover crops
Plant cover reduces erosion

• Plants anchor soil
  - Move livestock to prevent overgrazing
  - Cut fewer trees in an area
  - Plant vegetation along riverbanks and roadsides

• China’s huge tree-planting program slows erosion
  - But the monocultures are not ecologically functioning forests
Irrigation: productivity with problems

- **Irrigation** = artificially providing water to support agriculture
  - Unproductive regions become productive farmland
- **Waterlogging** = overirrigated soils
  - Water suffocates roots
- **Salinization** = the buildup of salts in surface soil layers
  - Worse in arid areas
  - Salinization inhibits production of 20% of irrigated cropland, costing over $11 billion/year
Preventing salinization

• It is easier and cheaper to prevent it than fix it
• Do not plant water-guzzling crops in sensitive areas
• Irrigate with low-salt water
• Irrigate efficiently
  - Use only water the crop requires
• Drip irrigation targets water directly to plants
Fertilizers boost yields but cause problems

- **Fertilizers** = substances containing essential nutrients
- **Inorganic fertilizers** = mined or synthetically manufactured mineral supplements
- **Organic fertilizers** = the remains or wastes of organisms
  - Manure, crop residues, fresh vegetation
  - *Compost* = produced when decomposers break down organic matter
Organic vs. inorganic fertilizers

• Organic fertilizers improve:
  - Soil structure
  - Nutrient retention
  - Water-retaining capacity

• Leaching and runoff of inorganic fertilizers
  - Dead zones in water systems
  - Contaminate groundwater
  - Nitrates volatilize (evaporate) into the air

*Inorganic fertilizer use has skyrocketed worldwide*
Environmental effects of overfertilizing
Overgrazing causes soil degradation

- **Overgrazing** = too many animals eat too much of the plant cover
  - Impedes plant regrowth
- Soil is degraded and compacted
- U.S. government subsidies increase harm
  - Few incentives to protect rangeland

70% of the world’s rangeland is classified as degraded, costing $23.3 billion/year
Effects of overgrazing can be striking

- Erosion increases, making it hard for plants to grow
- Non-native invasive species invade
  - Less palatable to livestock
  - Outcompete native vegetation

Grazed plot — Ungrazed plot
Agricultural policy

- Farming can be sustainable
  - No-till and organic farming, responsible grazing
- Industrial agriculture places huge demands on the land
- Degradation occurs slowly
  - But farmers need short-term profits
- Subsidies encourage cultivation on fragile land
  - Farmers should buy crop insurance instead
- Ranchers graze cattle extremely cheaply on BLM (Bureau of Land Management) land
- Environmentalists and ranchers work together against suburban sprawl
Wetlands have been drained for farming

- *Wetlands* = swamps, marshes, bogs, river floodplains
  - Over 50% have been drained for agriculture in the U.S.
- Government policy encouraged draining
  - Swamp Lands Acts (1849, 1850, 1860) = drained and converted wetlands to control floods and malaria
- Wetlands are now seen as vital ecosystems
  - Habitat, flood control, recharged water supplies
- Despite regulations, loopholes allow wetland losses
- *Wetlands Reserve Program* = landowners are paid to protect, restore, and enhance wetlands
U.S. programs promote soil conservation

- **Conservation Reserve Program** (1985): farmers are paid to put highly erodible land in conservation reserves
  - Trees and grasses are planted instead of crops
  - Each dollar spent saves 1 ton of topsoil
  - Generates income for farmers
  - Improves water quality
  - Provides habitat for native wildlife

- The 2008 farm bill limited reserve lands to 32 million acres
  - But funds 14 other similar land conservation programs
International soil conservation programs

- Food and Agriculture Organization (FAO) = the United Nations’ main agricultural program

- The FAO’s Farmer-Centered Agricultural Resource Management Program (FARM)
  - Supports innovative approaches to resource management and sustainable agriculture in Asia
  - Helps farmers duplicate agricultural success stories
  - Uses local communities to educate and encourage farmers to conserve soils and secure the food supply
Conclusion

• Programs in the U.S. and the world have been successful in reducing topsoil erosion

• These programs require research, education, funding, and commitment from farmers and governments

• To avoid a food crisis caused by population growth, we need:
  - Better technology
  - Wider adoption of soil conservation techniques
  - To consider Aldo Leopold’s land ethic program