ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 9

Soil and Agriculture

Part 2: Environmental Issues and the Search for Solutions

PowerPoint® Slides prepared by Jay Withgott and Heidi Marcum

The other inconvenient truth video

Third Edition

This lecture will help you understand:

- The relationship between soils and agriculture
- Major agricultural developments
- The fundamentals of soil science
- Causes and consequences of soil erosion and degradation
- Principles of soil conservation

No-till agriculture in Southern Brazil

- Southern Brazil's climate and soils make for bountiful harvests
- Repeated planting has diminished the productivity of the soil
- Leaving crop residues on their fields after harvesting and planting "cover crops" reduced erosion, increased yields and cut costs
- These no-till techniques have benefited everyone

Soil: the foundation for agriculture

- Land devoted to agriculture covers 38% of Earth's land surface
- **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 consisting of disintegrated rock, organic matter, water, gases, nutrients, and microorganism
  - It is a renewable resource

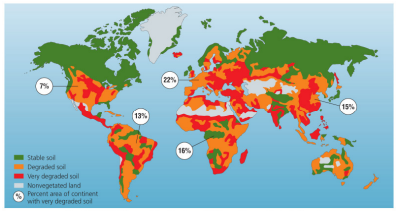
Population and consumption degrades soil

- Feeding the world's rising human population requires changing our diet or increasing agricultural production
- Land suitable for farming is running out
- We must find ways to improve the efficiency of food production
- Mismanaged agriculture turns grasslands into deserts; removes forests; diminishes biodiversity; and pollutes soil, air, and water
  - Fertile soil is blown and washed away

Millions of acres of cropland are lost each year

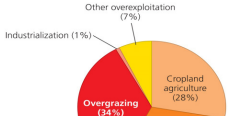
We lose 5-7 million ha (12-17 million acres) of productive cropland annually

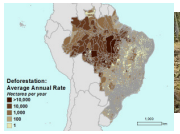
1 acre = 0.4 hectares



Soil degradation has many causes

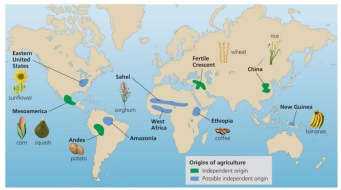
- Soil degradation results from deforestation, agriculture and overgrazing
- Over the past 50 years, soil degradation has reduced global grain production by 13%





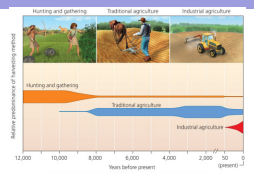
Agriculture arose 10,000 years ago

- Agriculture was invented independently by different cultures
- 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

- **Traditional agriculture** = biologically powered agriculture, using human and animal muscle power
  - **Subsistence agriculture** = families produce only enough food for themselves
  - **Intensive agriculture** = produces excess food to sell
  - Uses animals, irrigation and fertilizer, but not fossil fuels



Industrialized agriculture is a recent phenomenon

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

Green revolution = the use of new technology, crop varieties and farming practices introduced to developing countries

- Increased yields
- Created new problems and worsened old ones

Farming for the Future video

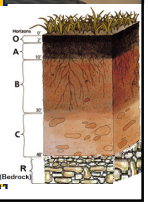
Soil as a system

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

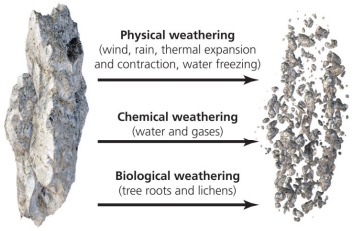
Since soil is composed of living and non-living matter, it is considered an ecosystem

Soil formation is slow and complex

- **Parent material** = the base geologic material of soil
  - Lava, volcanic ash, rock, dunes
  - **Bedrock** = the continuous mass of solid rock comprising the Earth's crust
- **Weathering** = the physical, chemical, or biological processes that break down rocks to form soil
  - **Physical (mechanical) =** wind and rain, no chemical changes in the parent material
  - **Chemical =** substances chemically interact with parent material
  - **Biological =** organisms break down parent material



Weathering produces soil



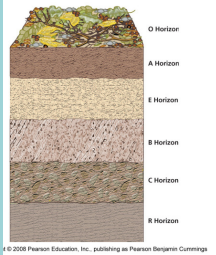
Other processes affect soil formation

Erosion = the dislodging and movement of soil by wind or water
- Occurs when vegetation is absent

- Biological activity includes deposition, decomposition, and accumulation of organic matter
  - **Humus** = a dark, spongy, crumbly mass of material formed by partial decomposition

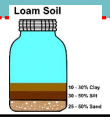
A soil profile consists of horizons

- **Horizon** = each layer of soil
- **Soil profile** = the cross-section of soil as a whole
- Up to six major horizons may occur in a soil profile
  - **Topsoil** = inorganic and organic material most nutritive for plants
  - **Leaching** = dissolved particles move down through horizons



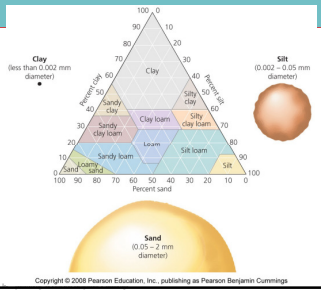
Soils are characterized in many ways

- Soils are classified based on 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
  - Influences how easy it is to cultivate and let air and water travel through the soil

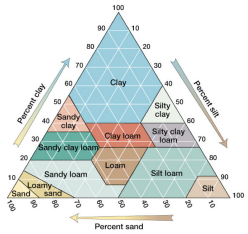


Soil texture classification

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



Animation



Part 2: Soil texture properties

Using the table below, determine the properties of each of the soil samples analyzed above.

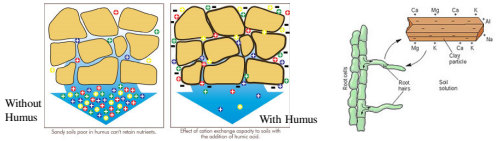
Soil texture	Nutrient-holding capacity	Water-infiltration capacity	Water-holding capacity	Aeration	Workability
Clay	Good	Poor	Good	Poor	Poor
Silt	Medium	Medium	Medium	Medium	Medium
Sand	Poor	Good	Poor	Good	Good
Loam	Medium	Medium	Medium	Medium	Medium

Soil structure and pH

- **Soil structure** = a measure of soil's "clumpiness"
  - Large clumps can discourage plant roots
  - Repeated tilling compacts soil, decreasing its water-absorbing capabilities
  - **Plowpan** = a hard layer resulting from repeated plowing that resists water infiltration and root penetration
- **Soil pH** = influences a soil's ability to support plant growth
  - Soils that are too acidic or basic can kill 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(Ca^+), magnesium (Mg^+), and potassium (K^+)
- **Cation exchange capacity** = a soil's ability to hold cations, preventing them from leaching, thereby increasing their availability to plants
  - A useful measure of soil fertility
  - Greatest in fine soils

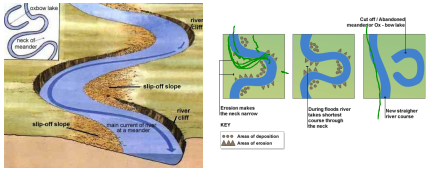


Regional differences in soils affect agriculture

- Rainforests have high primary productivity, but the nutrients are in plants, not the soil
  - Rain leaches minerals and nutrients deeper into the soil, reducing their accessibility to roots
  - **Swidden agriculture** = cultivation of a plot for a few years and then letting it regrow into forest
- Temperate grasslands have lower rainfall and less nutrient leaching

Erosion degrades ecosystems and agriculture

- **Deposition** = the arrival of eroded material at its new location
- Flowing water deposits sediment in river valleys and deltas
  - Floodplains are excellent for farming
- But, erosion is a problem because it occurs faster than new soil is formed
- Erosion increases through: excessive tilling, overgrazing, and clearing forests



Soil erodes by several methods

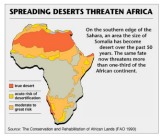
- Plants protect soils form erosion
  - Removing plants accelerates erosion
- Rill erosion moves the most topsoil, followed by sheet and splash forms of erosion
- Water erosion occurs most easily on steep slopes
- Erosion in the U.S. declined between 1982 and 2001
  - Soil conservation measures

Despite conservation measures, the U.S. still loses 6 tons of soil for every ton of grain harvested

Various types of soil erosion

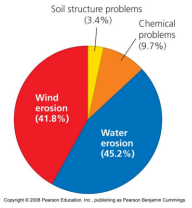
Soil erosion is a global problem

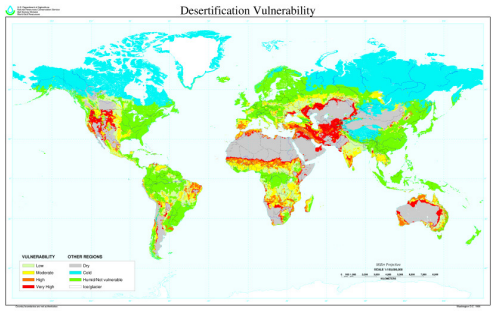
- Humans are the primary cause of erosion
  - It is occurring at unnaturally high rates
- In Africa, erosion over the next 40 years could reduce crop yields by half
  - Coupled with rapid population growth, some observers describe the future of agriculture as a crisis situation



Desertification

- **Desertification** = a loss of more than 10% productivity
  - Erosion, soil compaction, forest removal, overgrazing, salinization, climate change, depletion of water sources
- Most prone areas = arid and semiarid lands





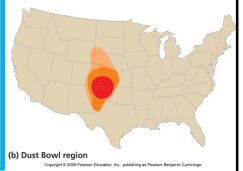
Desertification has high costs

- Desertification affects 1/3 of the planet's land area
  - In over 100 countries
- Costs tens of billions of dollars each year
  - China loses over $6.5 billion/year alone from goat overgrazing
  - In Kenya, 80% of he land is vulnerable to desertification from overgrazing and deforestation

The Dust Bowl

- In the late 19th and early 20th centuries, settlers arrived in Oklahoma, Texas, Kansas, New Mexico and Colorado
- Grew wheat, grazed cattle
  - Removed vegetation
- A drought in the 1930s made conditions worse
- Thousands of farmers left their land and had to rely on governmental help

(a) Kansas dust storm, 1930s



(b) Dust Bowl region

The Soil Conservation Service

- Started in 1935, the Service works with farmers to develop conservation plans for farms
  - Assess the land
  - Prepare an integrated plan
  - Work closely with landowners
  - Implement conservation measures
- **Conservation districts** = districts operate with federal direction, authorization, and funding, but are organized by the states

Conservation districts

- Districts implement soil conservation programs to empower local residents to plan and set priorities
- **Natural Resources Conservation Service** = 1994 renaming of the Soil Conservation Service
  - Expanded responsibilities include water quality protection and pollution control
  - Serves as a model for efforts around the world

Protecting soil: crop rotation and contour farming

- **Crop Rotation** = alternating the crops grown field from one season or year to the next,
  - Cover crops protect soil when main crops aren't planted
  - Wheat or corn and soybeans
- **Contour Farming** = plowing furrows sideways across a hillside, perpendicular to its slope, to prevent rills and gullies

(a) Crop rotation

(b) Contour farming

Protecting soil: terracing and intercropping

- **Terracing** = level platforms are cut into steep hillsides, sometimes with raised edges
  - A "staircase" to contain water
- **Intercropping** = planting different types of crops in alternating bands or other spatially mixed arrangements
  - Increases ground cover

(c) Terracing

(d) Intercropping

Protecting soil: shelterbelts and reduced tillage

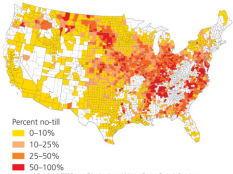
- **Shelterbelts or Windbreaks** = rows of trees or other tall, perennial plants that are planted along the edges of fields to slow the wind
  - **Alley cropping** = shelterbelts + intercropping
- **Reduced Tillage** = furrows are cut in the soil, a seed is dropped in and the furrow is closed
  - **No-till farming** disturbs the soil even less

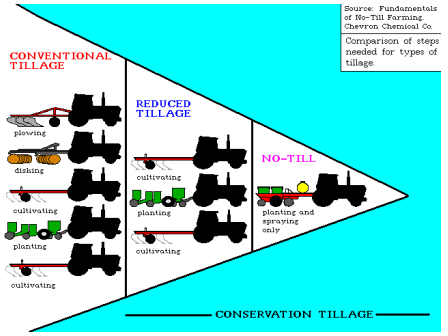
(e) Shelterbelts

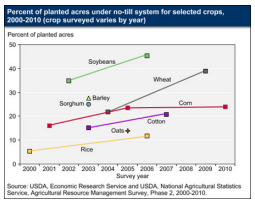
(f) No-till farming

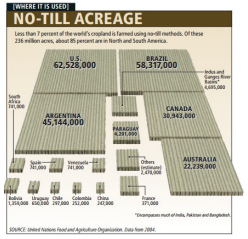
Pros and cons of no-till farming

- Almost half of U.S. farmland uses no-till farming
- Benefits: reduced soil erosion, greater crop yields, enhanced soils
- Negatives: increased use of herbicides and fertilizers
- But, **green manure** (dead plants and fertilizer) and rotating crops minimizes the negatives









Plant cover reduces erosion

- Eroding banks along creeks and roadsides are stabilized by planting plants to anchor soil
- China has the world's largest tree-planting program
  - It does slow erosion
  - But it does not create ecologically functional forests, because monocultures are planted

Irrigation: boosted productivity, but problems, too

- **Irrigation** = Artificially providing water to support agriculture
  - Unproductive regions become farmland
- **Waterlogging** = over-irrigated soils
  - Water suffocates roots
- **Salinization** = the buildup of salts in surface soil layers
  - Worse in arid areas


(a) Conventional irrigation

Salinization inhibits production of 20% of all irrigated cropland, costing more than $11 billion/year

Salinization prevention

- It is easier and cheaper to prevent salinization than fix it
- Do not plant water-guzzling crops in sensitive areas
- Irrigate with low-salt water
- Irrigate efficiently, supplying only water that the crop requires
  - **Drip irrigation** targets water directly to plants


(b) Center-pivot irrigation, aerial view


(c) Drip irrigation

Fertilizers boost yields but cause problems

- **Fertilizer** = substances that contain 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

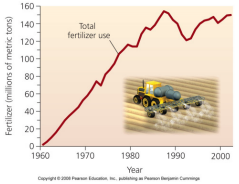

(a)

Applying synthetic fertilizer, vs. Planting rye, a "green manure"

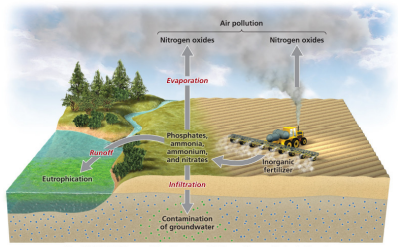

(b)

Overapplication of Fertilizer

- Inorganic fertilizer use has skyrocketed
- Overapplying fertilizer can ruin the soil and severely pollute several areas
- Runoff causes eutrophication in nearby water systems
- Nitrates leach through soil and contaminate groundwater
- Nitrates can also volatilize (evaporate) into the air

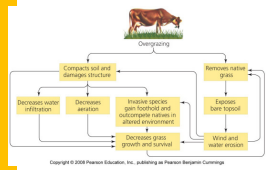


Environmental effects of over-fertilizing



Overgrazing causes soil degradation

- **Overgrazing** = too many animals eat too much of the plant cover
  - Impedes plant regrowth
- A leading cause of soil degradation
- Government subsidies provide few incentives to protect rangeland

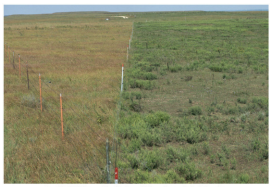


70% of the world's rangeland is classified as degraded

Effects of overgrazing can be striking

- Non-native invasive species invade
  - Less palatable to livestock
  - Out compete native vegetation

Ungrazed plot



Grazed plot

Forestry impacts soil

- Along with farming and ranching, forestry impacts soils
- **Clear-cutting** = the removal of all trees from an area at once
  - Leads to soil erosion, especially on steep slopes
- Modern methods remove fewer trees over longer periods of time
  - Minimizes soil erosion

U.S. programs promote soil conservation

- **Food Security Act of 1985**: Farmers that adopt soil conservation plan receive price supports and other benefits
- **Conservation Reserve Program** (1985)
  - Farmers are paid to place highly erodible land into conservation reserves
  - Trees and grasses are planted instead of crops
  - Saves 771 million tons of topsoil per year
  - Generates income for farmers
  - Provides habitat for native wildlife

Federal Agricultural Improvement Act (1996)

- Known as the Freedom to Farm Act
  - Aimed to reduce subsidies and government influence over farm products
  - Created the Environmental Quality Incentive Program and Natural Resource Conservation Foundation
  - Promotes and pays for conservation practices in agriculture
- Low-Input Sustainable Agriculture Program (1998)
  - Provides funding for sustainable agricultural practices for individual farmers

International soil conservation programs

- Food and Agriculture Organization (FAO) = the United Nations' main agricultural program
- The FAO's **Farmer-Centered Agricultural Resource Management Program (FAR)…**
  - Helps farmers duplicate agricultural success stories
  - Uses local communities to educate and encourage farmers to conserve soils and secure the food supply
  - Supports innovative approaches to resource management and sustainable agriculture in around the world
  - China, Thailand, Vietnam, Indonesia, Sri Lanka, Nepal

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