Soil, Agriculture and Food Production: sustaining earth to sustain us.

Opportunities and problems facing a growing population in the face of environmental, social, and economic change.

World food production faces a serious decline within the century due to climate change.

UN FAO Sept 2007 special session

2080’s 5-20% decline in agricultural output.

IMPORTANT: 30-40% in India, 20-30% in Africa, with some countries experiencing some gain (mostly temperate countries). Sudan and Senegal could experience collapse: >50% decline.

Soil Resources

• Soil:
  – probably most valuable natural resource after water
  – although renewable, it is produced very slowly, 200-1000 years to form 1 inch of topsoil; if topsoil erodes faster than it is renewed, soil becomes a nonrenewable resource.
  – most of the world’s crops are grown on cleared grassland (e.g. US midwest) and deciduous forest soils. Why??
  – Soil fertility and topsoil

Factors determining type of soil and rate of development:

• Parent Material
• Time
• Climate
• Plants
• Animals
• Slope

Soil quality is a major determinant of plant distribution and growth

Along with climate, the major factors determining whether particular plants can grow well in a certain location are the texture and composition of the soil

• Texture
  – Is the soil’s general structure
• Composition
  – Refers to the soil’s organic and inorganic chemical components

Soil Type

• Porosity: ‘sponginess’ and ability to hold water
• Permeability: rate at which water passes through it
• Acidity

• These factors all contribute to which kinds of plants can successfully be grown
• **Nitrogen** is often the mineral that has the greatest effect on plant growth

• Plants require nitrogen as a component of proteins, nucleic acids, chlorophyll, and other important organic molecules

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**Soil Bacteria and Nitrogen Availability**

- Nitrogen-fixing bacteria convert atmospheric N\(_2\) to nitrogenous minerals that plants can absorb as a nitrogen source for organic synthesis

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- **Symbiotic relationships** with nitrogen-fixing bacteria provide some plant species with a built-in source of fixed nitrogen

- One of the most important and efficient symbioses between plants and nitrogen-fixing bacteria occur in the legume family (peas, beans, and other similar plants)

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**Symbiotic Nitrogen Fixation and Agriculture**

- The agriculture benefits of symbiotic nitrogen fixation underlie **crop rotation**

- In this practice a non-legume such as maize is planted one year, and the following year a legume is planted to restore the concentration of nitrogen in the soil

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**Topsoil** is a mixture of rock (inorganic) and organic material (breakdown of humus)

- Topsoil loss ranges from 1700-5000 t/Km\(^2\)/yr
- Accumulation rates are highest in grasslands - 100t/Km\(^2\)/yr
- 50,000 km\(^2\)/year of arable land are lost to wind- and water erosion, salination, sodification, and desertification
Mature soils have distinct layers or zones called Soil Horizons; cross-sectional views of soil horizons are called Soil Profiles.

Soil erosion and fertility loss

- Soil erosion:
  - movement of topsoil, mainly by flowing water and wind, from one place to another
  - natural process/rock cycle that occurs to all soils; when rate of erosion exceeds rate of formation -> soil loss.
  - human activities such as farming, logging, mining, construction, overgrazing, off-road vehicles, burning vegetation all may accelerate soil erosion

Soil cover and erosion

**TABLE 7.2 Soil Cover and Soil Erosion**

<table>
<thead>
<tr>
<th>CROPPING SYSTEM</th>
<th>AVERAGE ANNUAL SOIL LOSS (tons/section)</th>
<th>PERCENT RAINFALL RUNOFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare soil (no crop)</td>
<td>41.0</td>
<td>30</td>
</tr>
<tr>
<td>Continuous corn</td>
<td>19.7</td>
<td>29</td>
</tr>
<tr>
<td>Continuous wheat</td>
<td>10.1</td>
<td>23</td>
</tr>
<tr>
<td>Rotation: corn, wheat, clover</td>
<td>2.7</td>
<td>14</td>
</tr>
<tr>
<td>Continuous bluegrass</td>
<td>0.3</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Based on 14 years of data from Missouri Experiment Station, Columbia, Missouri.

**EROSION: causes**

- **Wind** and **water** are the major forces

  - Exacerbated by
    - Overgrazing
    - Deforestation
    - Cultivating marginal farmlands
    - Poor farming techniques

Preventing erosion

- Terracing
- Contour farming
- Crop rotation
- Never leave fields bare! Use ‘cover crops’
- Organic fertilizers
- Wind breaks
- Stop deforestation
- Stop overgrazing
Soil conservation: reducing soil erosion and restoring soil fertility

- **Conservation tillage farming**: disturb soil as little as possible; machines till subsurface soil w/out breaking up topsoil or inject seeds into unplowed soil. By 2001 used on 45% of US cropland.
- **Terracing**: converting a slope into a series of step-like platforms; retains water and reduces erosion.

Certain precautions can reduce the loss of topsoil: role of grazing animals?

### Soil Conservation Practices

<table>
<thead>
<tr>
<th>Practice</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terracing</td>
<td>Creating flat areas on sloping ground, one of the oldest and most effective ways of preventing soil and water erosion.</td>
</tr>
<tr>
<td>Strip cropping</td>
<td>Growing of different crops on alternate, parallel strips of ground to minimize wind and water erosion. Alternating rows of corn and alfalfa for resilience.</td>
</tr>
<tr>
<td>Crop Rotation</td>
<td>Yearly alternation of crops on the same land; significant reduction in soil erosion when soil-depleting crops are alternated with soil-enriching crops.</td>
</tr>
<tr>
<td>Contour Planting</td>
<td>Plowing along a slope contours so that furrows and ridges are perpendicular to the slope.</td>
</tr>
<tr>
<td>No-till Planting</td>
<td>Planting seeds through the residue of a previously harvested crop.</td>
</tr>
<tr>
<td>Windbreaks</td>
<td>Planting trees or large shrubs along the margins of a field, especially effective in reducing wind erosion.</td>
</tr>
</tbody>
</table>

**Types of Agriculture**

- **Industrialized**: Primarily MDCs. High Fossil Fuel use, oil, Nat gas, solar and oil. Single crop or livestock. Intensive breeding/selection through (MDCs) genetic engineering.
- **Plantation agriculture**: $SCash crops for MDCs, export: Bananas, coffee, pineapples, tobacco (LDCs)
- **Traditional**: Used on about 70% of the world’s lands, by 2.9 billion people (1/2 of earth) 
  - Intensive (large farm) (LDCs) 
  - Subsistence (Family)

**Feeding the world**

- Corn used to make a 25-gallon tank of ethanol would feed one person for a year.
- China raises half of the world’s pigs, and imports tons of grain to feed them.
- In the Philippines, record harvests have not been enough to feed 90 million people. It is now one of the leading rice importers.
- Grain production has generally kept up with demand. BUT, consumption was greater than production in 7 of the past 9 years.
- Low stockpiles (for emergencies) and high grain prices.
Feeding the world

- Malnutrition and food distribution
- Food (crop) production
- Crop area and arable land is decreasing (erosion and soil quality degradation)

Undernourished vrs. Overnourished

Overnutrition:
- 15% people in Developed countries suffer from various forms of overnutrition: 2/3 deaths in U.S!!
- In the U.S, 38 million people spend $38 billion per year on diet programs. That is $5 per day per hungry person!!

Undernutrition:
- 1/4 people on earth are too weak to work or think clearly
- 1.7 bill people don't get enough quality food

Poverty, not lack of food is the real problem: food distribution

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Enough good food to eat?

- Marasmus and Kwashiorkor (PEM): Protein and energy deficiency, mostly in just weaned children
- Affects 50 million children younger than 5 years
- 10 million children/yr die in developing countries: 55% (WHO) attributable to PEM
- It occurs in the US too
- Proper nutrition is essential, but food distribution problems are immense
- In part due to regional problems with agriculture

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Per capita food production

Source: Data from Food and Agriculture Organization of the United Nations (FAO), FAOSTAT (FAO, Rome, 2000).
Crop Yields per person

- Population growth rates are going down
- Food/grain production is increasing
- Per capita food production is going down in high population growth rate regions
- Global warming will most likely have an effect on crop production
- Food shortages are likely around the globe
- Arable land is decreasing (per capita)-448 million people live without enough of it
- Clear more land? Grow different crops? Consequences?

What does it all mean??

We know that clearing marginal land is NOT the answer, but a growing problem

BR-319 in Brazil – 475 miles. Approved

THE GREEN REVOLUTION: Increasing yields per hectare
MDCs 1950-1970, LDCs later with aid
1) Monocultures of genetically engineered plants and animals: fast growing, stay fresh longer etc.
   - Fast growing recombinants allow for multiple croppings major incr. (yields)
   - Prob w/ monoculture = reduction in biodiversity
   - Genetically engineered resistance
   - Gene banks to preserve biodiversity
2) Increased use of inorganic fertilizers (ie. phos), 3) fac use of water
4) fac use of pesticides
5) 2-4 led to increased use of Machines for irrig etc. (high input of energy)

Climate change will have an effect on agricultural output, but how?

*Rice may be particularly hard hit
Climate Change and rainfall: projections 1971-2000 average to 2041-2070 average (% change)

Central Asia, Canada, East coast US
South Eastern Africa: +30-50%
Southwest and Northern Africa, Southern US, Australia, China: -10-40%

*Parts of the Sahara Desert will green a bit!

See National Geographic, April 2009 issue

The global distribution of C₄ plants

C₄ grasslands (orange) have evolved in the tropics and warm temperate regions forests (green) are excluded by seasonal drought or fire.

C₃ plants (yellow) remain dominant in cool temperate grasslands because C₄ grasses are less productive at low temperatures.

We need a new green revolution in half the time it took us in the 70's

Before:
- Irrigation
- Dwarf varieties (fertilizers)
- Pesticides
- Synthetic fertilizers

Now:
- Breeding (and GM) for drought tolerance, pests photosynthetic rates
- Sustainable farming: increasing soil fertility
- Smart irrigation: mulch, drip irrigation, cover crops...

Pesticides

What is a pest? Any organism which is unwanted or causes problems to humans.

- Microbes (BT, viruses, fungi, some tiny worms)
- Critters that transmit disease, like mosquitoes, flies, etc.
- Organisms that eat our plants: insects, birds, mice, snails, slugs, rats.
- Animals that attack and kill our domestic animals: wolves, coyotes, foxes, raccoons.
- Organisms that cause rotting of wood, food, other valuables. Mainly fungi.
- Weeds, plants that compete with our crops or ornamentals.

An Ideal pesticide should

- Kill only target pest
- Have no short or long term health effects on humans
- Be broken down into harmless chemicals in a fairly short time
- Prevent the development of genetic resistance in the target organism
**Categories of pesticides**
- Chemical
- Biological
- Natural

**Types of pesticides**
- Insecticide
- Herbicide
- Fungicide
- Rodenticide

**Benefits:**
- Disease control (DDT, Malathion, Mosquitos, Florida!)
- Increase food supplies (crop protection)
- Increase farmers profits
- Increase pesticide company profits

**Problems:**
- Genetic resistance:
- Imbalance in the ecosystem:
- Pesticide treadmill:
- Persistence:
- Mobility: air, soil and water movement
- Health risks to humans!

**Integrated Pest Management (IPM)**
- Using several techniques:
  - Crop rotation
  - Interplanting
  - Combine natural and chemical pest control
- Requires knowledge of fields and natural cycles