# Land Degradation

Picture from the National Archives, taken during
the "Dust Bowl" in the 1930's

***"The objective of this convention is to combat desertification and mitigate the effects of drought in countries... particularly in Africa... in the framework of an integrated approach ... with a view to contributing to the achievement of sustainable development in the affected areas."***

Convention to Combat Desertification, Rio de Janeiro, 1994.

***"A process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life"***

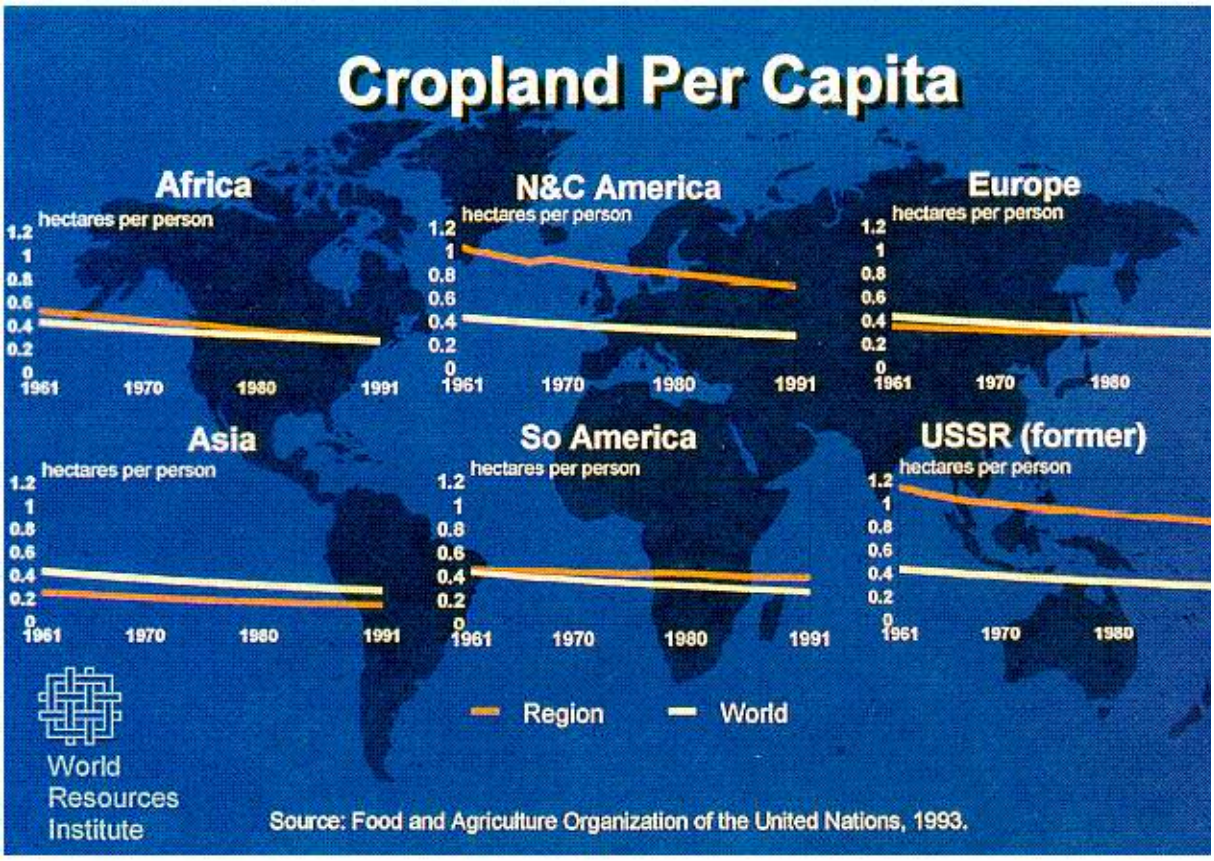
**GLASOD - First United Nations Global Assessment of Human-Induced Soil Degradation, 1988-90.**

**We wish to learn:**

- What are the primary causes of land degradation?
- What is desertification and what management strategies can be used to mitigate negative effects

## 1. Croplands

The world's croplands are in decline due to the pressure of human activities. The figure shows the regional and global trends in the total available area of the world's croplands.



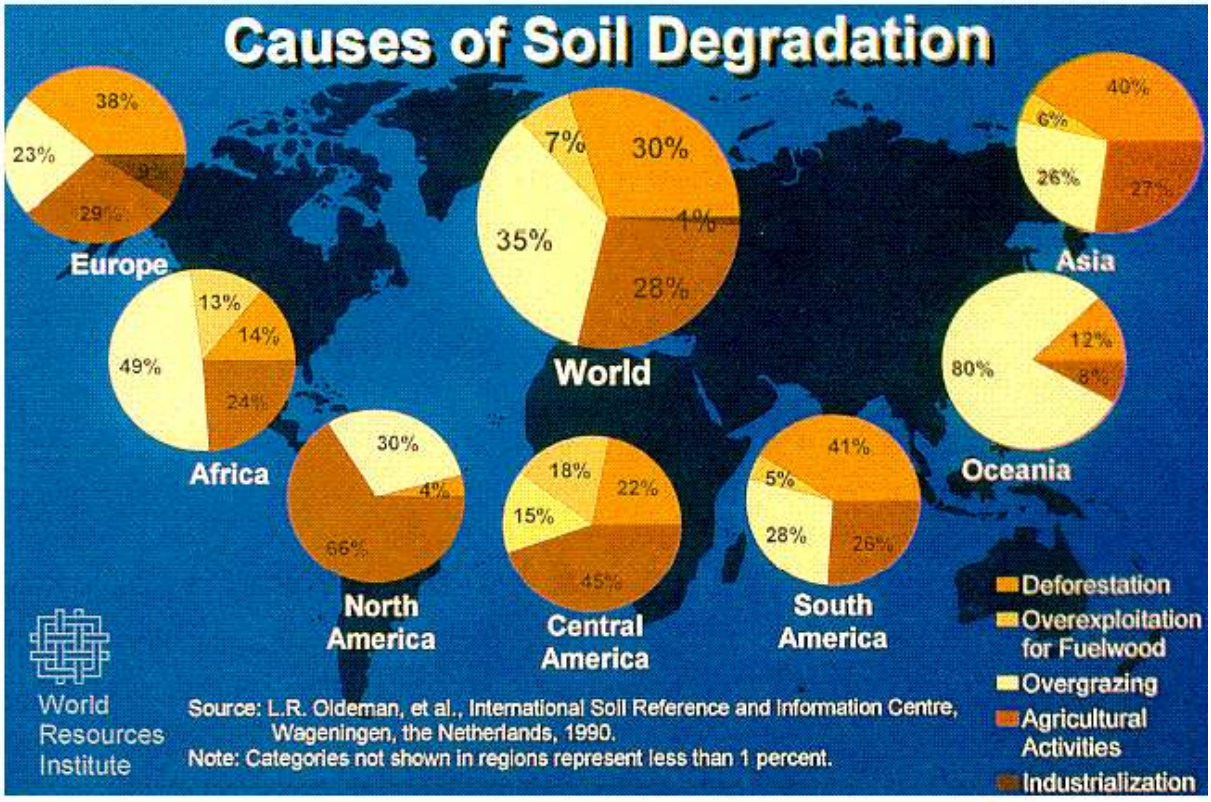

*Worldwide the amount of cropland per capita has declined due to population growth. North America and the former USSR have substantially more cropland per capita than the rest of the world.*

The first global survey of soil degradation was carried out by the United nations in 1988-91. This survey, known as GLASOD - for Global Survey of Human-Induced Soil Degradation, has shown significant problems in virtually all parts of the world. The yellow line in each panel shows the global cropland area per person. Obviously, this indicator is a function of two factors: human population and cropland area. It has shown a steady decline in the 30 years from 1961 to 1991, amounting to a decrease of between 20 and 30%. The figure illustrates the regional changes that have accompanied this global change. North and central America and the former USSR are regions with significantly higher cropland areas per capita. However, all regions, including these, have shown decreases. South America croplands have declined at a rate that is slower than the global average, while African per capita croplands have declined at a greater than average rate.

### What are the causes of this degradation?

The loss of arable land has been caused by a number of factors, many or most of which are tied to human development. The primary causes are deforestation, overexploitation for fuelwood, overgrazing, agricultural activities and industrialization.

The following figure illustrates the relative sizes of the causal mechanisms as a function of region.

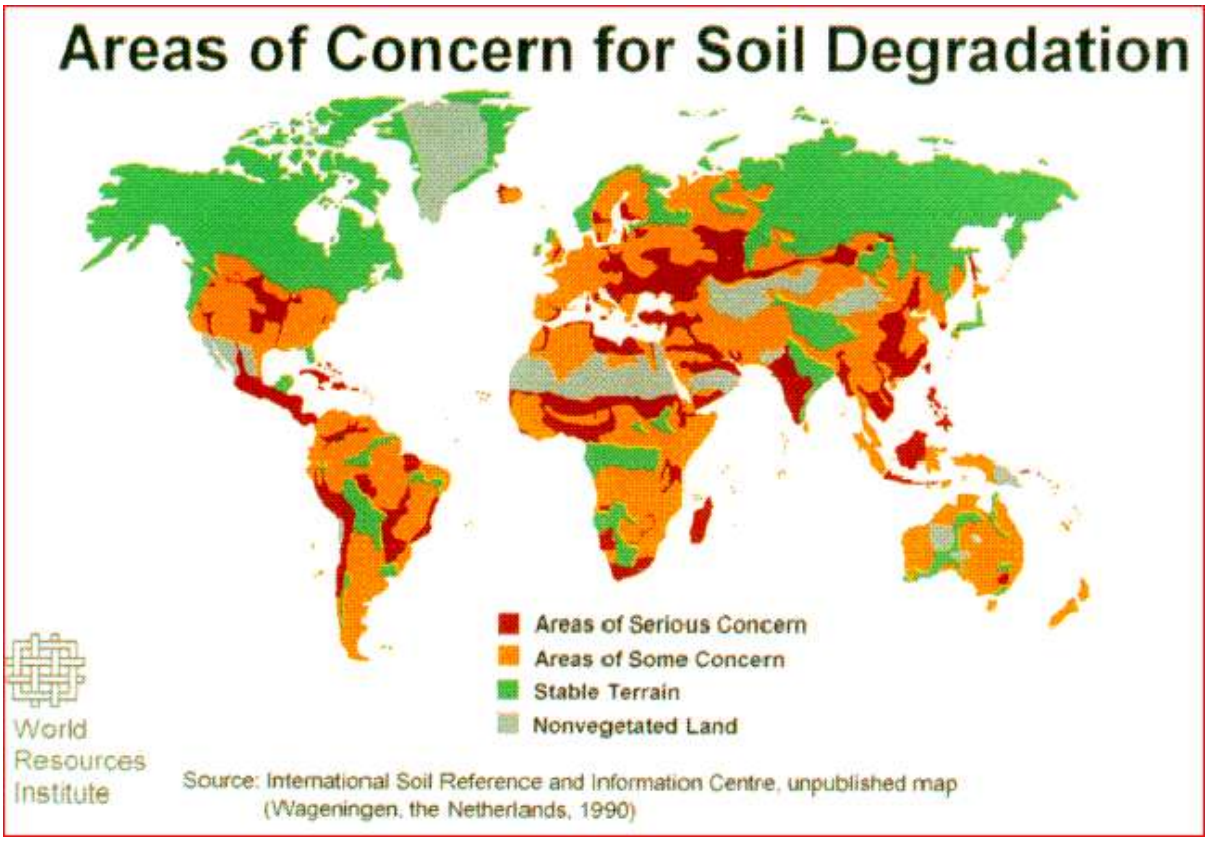



*Worldwide the amount of cropland per capita has declined due to population growth. North America and the former USSR have substantially more cropland per capita than the rest of the world.*

On the global basis, the soil degradation is caused primarily by overgrazing (35%), agricultural activities (28%), deforestation (30%), overexplotation of land to produce fuelwood (7%), and industrialization (4%).

The patterns are different in the various regions. In North America, agriculture has been responsible for 66% of the soil loss, while in Africa, overgrazing is responsible for about half of the soil degradation.

The economic reasons for these processes are complex and are linked to the particular characteristics of each region. Some of these issues will be discussed later in the course, as part of case studies.




*Of the world's 1.2 billion hectares with moderate to severe soil degradation, the largest areas are in Asia and Africa. Central America has the highest percentage and worst degrees of soil degradation*

This figure illustrates how pervasive is the problem of soil degradation. No continent is free from the problem. Areas of serious concern include zones where up to 75% of the topsoil has been lost already. The central portion of the United States is an area of particular local concern. The practices of large scale mechanized monoculture has contributed to the decline in soil in the mid-west.

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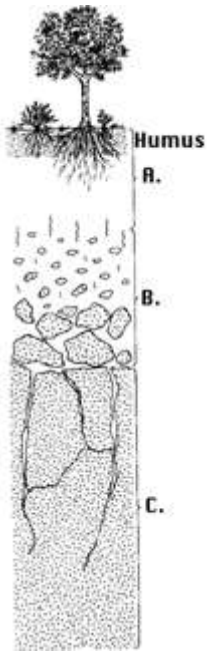
## 2. Soils

All our amino acids and nutrients eventually come to us from plant life (sometimes via the meat of plant-eating animals). Plants synthesize amino acids from the combination of *sunlight, water and soils.*



*Layers of Horizons of a typical soil profile*

Soil is therefore of critical importance to life. Simply put: **no soil, no life**.

We first define soil as a *dynamic natural body capable of supporting a vegetative cover.* Where there is no soil, there is no plant life and we have barren rock and/or sand. Soil is composed primarily of *weathered* materials, along with water, oxygen and organic materials. Luckily for us, soil covers most of the land surface with a fragile, thin mantle. Soil and agricultural scientists have identified a huge number of different soil types.

**Soil is layered**

Soil is layered into sections called "horizons". The figure shows a typical soil profile developed on granite bedrock in a temperate region. The top horizon is composed of *humus* and contains most of the organic matter. This layer is often the darkest. The "A" horizon consists of tiny particles of decayed leaves, twigs and animal remains. The minerals in the A-horizon are mostly clays and other insoluble minerals. Minerals that dissolve in water are found at greater depths. The "B" horizon has relatively little organic material, but contains the soluble materials that are *leached* downwards from above. The "C" horizon is slightly broken-up bedrock, typically found 1-10 meters below the surface. While this is a typical soil profile, many other types exist, depending on climate, local rock conditions and the community of organisms living nearby. The U.S. Department of Agriculture has classified 10 orders and 47 suborders of soils. If you include other subsets, there are over 60,000 types of soil. The lunar surface, which has been produced by meteoroid impacts, is not classified as a soil, but is rather given the name "regolith" (derived from the Greek words meaning cover and stone).

The layered nature of soil indicates its long evolution under the effects of atmospheric and biological processes. The process that creates soil from bare rock is called "weathering". In the weathering process, the atmosphere and water interact with bare rock to slowly break it down into smaller and smaller particles. Rock climbers who encounter talus slopes (regions of pebble-life rocks that form in great conical piles at the feet of mountains) experience an intermediate step in the inexorable transition from solid granite to sand and soil.

Soil is generated by the process called weathering. This is a very slow process - and one that depends a lot on the local conditions. For example, consider what happens if you drop an iron nail in a garden in Michigan. After a few years, you would be able to break it in two, because it has degraded - or rusted. If, however, you were to drop the same nail in a dry environment - for example in Egypt or in Antarctica - it would last for hundreds of years before rusting. Aluminium cans decay very slowly and glass decays even more slowly. Plastic is considered "biodegradable".

Soil itself is an important agent in weathering. When soil is present, rocks weather much more quickly into soil. Thus, soil is both a factor in weathering - and a product of weathering.

Rates of weathering achange from place to place and from rock type to rock type. The following weathering rates are in units of micro-meters per thousand years:

- Basalt Cold climate: 10; warm, humid climate: 100
- Granite Cold climate: 1; warm, humid climate: 10
- Marble Cold climate: 20; warm, humid climate: 200

The bottom line on soil production is that it takes (on average) about 100 years to generate a millimeter of soil. This is about a human lifetime. So, you can see that soil geneation is a very slow process indeed on human time scales.

**Soil is an important source of nutrients**

**Percentage of annual requirement of nutrients for growth of northern hardwood forest (Hubbard Brook, new Hampshire)**

| nutrient | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Growth requirement (kg/hectare/yr) | 115 | 12 | 67 | 62 | 9.5 |
| from atmosphere | 18 | 0 | 1 | 4 | 6 |
| from rocks | 0 | 13 | 11 | 34 | 37 |
| from re-absorption | 31 | 28 | 4 | 0 | 2 |
| from detritus turnover | 69 | 81 | 86 | 85 | 87 |

This table shows the results of a famous experiment that was carried out at Hubbard Brook, New Hampshire. The purpose of the experiment was to determine where the nutrients plants need come from. The table compares the annual requirement of several important nutrients, with annual supply rates from the important sources. As you can see, the largest annual sources come from the detritus turnover - i.e., nutrients stored in the topsoil.

From experiments like this, it is possible to see that the pool of nutrients held in the soil and vegetation is many times larger than the annual receipt of nutrients from the atmosphere and from rock weathering. What this means is that life *husbands* nutrients very effectively on land in the soil, storing much of the total needed for plant life in the humus or topsoil.

So, we can see that soil is very important for storing the essential nutrients needed by plants. Simply put: No soil, no life!

The total loss of arable land can be summarized in the following figure. Of the total available (1500 million hectares, signifant components have been lost due to the combined effects of desertification, salinization, erosion, and development activities.

**When soil is lost - where does it go?**

When topsoil is mobilized and gets into the hydrological cycle - it gets literally washed to the sea. The topsoil becomes silt and traqvels down streams and rivers, ultimately reaching the sea. The process is responsible for a *sink* of topsoil. You can see a dramatic example of sediment output from the Amazon river as seen from space.

## 3. Soil Degradation Processes

**Erosion**

Erosion is the term given to soil loss due to the mobilization of topsoil by the forces of water and wind. Wind and water move the eroded particles to some other location, where it is deposited as sediment. Soil erosion is a natural process that removes soil from the land.

The critical aspect of soil erosion for our purposes here is that the rate of the process is highly dependent on human actions. Natural rates of soil erosion are lower for soil with a good cover of vegetation than for bare soil. In fact, any human actions that uncover soil (e.g., farming, logging, building, overgrazing, off-road vehicles, fires, etc.) greatlty enhance soil erosion rates.

During the last dust bowl in the 1930's more than 30 million hectares were severely damaged in parts of Texas, Kansas, Oklahoma, and Colorado. The Dust Bowl was primarily caused by the two factors of: 1) loss of long rooted grasses due to the plowing of the prairies and 2) a period of relative drought.

Erosion is a global problem, as we have already seen. Globally, topsoil is eroding faster than it can be replaced over 1/3 of the world's croplands. In the U.S., the loss of topsoil has been estimated to cost $125B per year. As you might imagine, this is a very difficult calculation to perfrorm, since topsoil production rates are so slow, the lost topsoil is essentially irreplaceable.

**Desertification**

Desertification occurs whenever a non-desert area starts to exhibit the characteristics of a true desert. The term was coined by the United Nations in 1977.

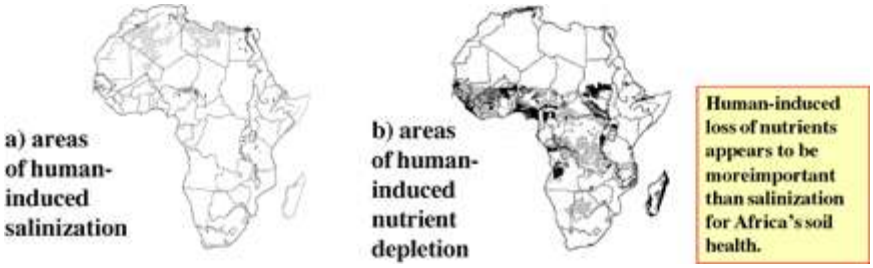
Over the past 50 years, at the southern edge of the Sahara, an area the size of Somalia has become desert. The same fate now threatens more than one-third of the African continent. The main cause of desertification is not drought, but mismanagement of land, including overgrazing and felling of trees and brushwood for fuel.

**Salinization and Nutrient Loss**

Soil salinization is the concentration of salts in the surface or near surface of soils. Human induced salinization is a major problem in drylands and is often associated with large-scale irrigation.

When drylands are irrigated, the water evaporates quickly, leaving behind previously dissolved salts. These salts can collect, since there is little rain to flush the system. The salt in the soil inhibits the uptake of water by plant roots and the soil can no longer sustain a vegetative cover.

Nutrient loss is an important problem in regions of *low-input* agriculture, such as in Africa. In such regions, when cops are harvested, essential nutrients are taken away in the crop and not replaced.




**Restoration**

We have discussed some of the major problems in soil degradation. Can degraded soils be restored to full function? This turns out to be a significant problem.

In general *lightly degraded soils* can be improved by crop rotation, minimum tillage techniques (next lecture), and other farm practices. More severely degraded soils are more difficult to restore.

*Moderately damaged land* takes more resources than an average farmer has to restore. Changes in soil conservation practices can slow land degradation, but not restore fertility often. National programs will be needed for such lands, requiring major structural change (e.g., draining, contour banks, etc.)

*Severely eroded land* generally is simply abandoned. Restoration efforts are simply beyond developing countries - requiring deep ditches for drainage, terraces to hold the soil in place, mechanized deep plowing to remove compaction, reseeding programs, etc.

## 4. Summary

- Degradation of land includes soil erosion, salinization, nutrient depletion, and desertification. The rate of degradation has increased dramatically with growth in human populations and technology.

- Severe land damage accompanies large scale agriculture. Restoration is very problematical.

- Continued loss of arable land will jeopardize our ability to feed the world population.

- Land degradation is worldwide - both developed and developing countries.

## 5. Suggested Readings


- World Resources 1992-1999: A Guide to the Global Environment, Oxford, 1992

- F. T. Mackenzie and J. A. Mackenzie, Our Changing Earth: An Introduction to Earth System Science and Global Environmental Change, Prentice Hall, 1995


http://www.globalchange.umich.edu/globalchange2/current/lectures/land_deg/land_deg.html