AP Environmental Science

Unit Two

ROCKS and SOIL

Unit Two

Rocks: Composition and Properties

Unit Two

Rocks and Minerals

- A mineral is an inorganic, solid element or compound with a definite chemical composition and regular internal crystal structure.

Rocks and Minerals

- A rock is a solid, cohesive, aggregate of one or more minerals.
  - Each rock has a characteristic mixture of minerals, grain sizes, and ways in which the grains are held together.

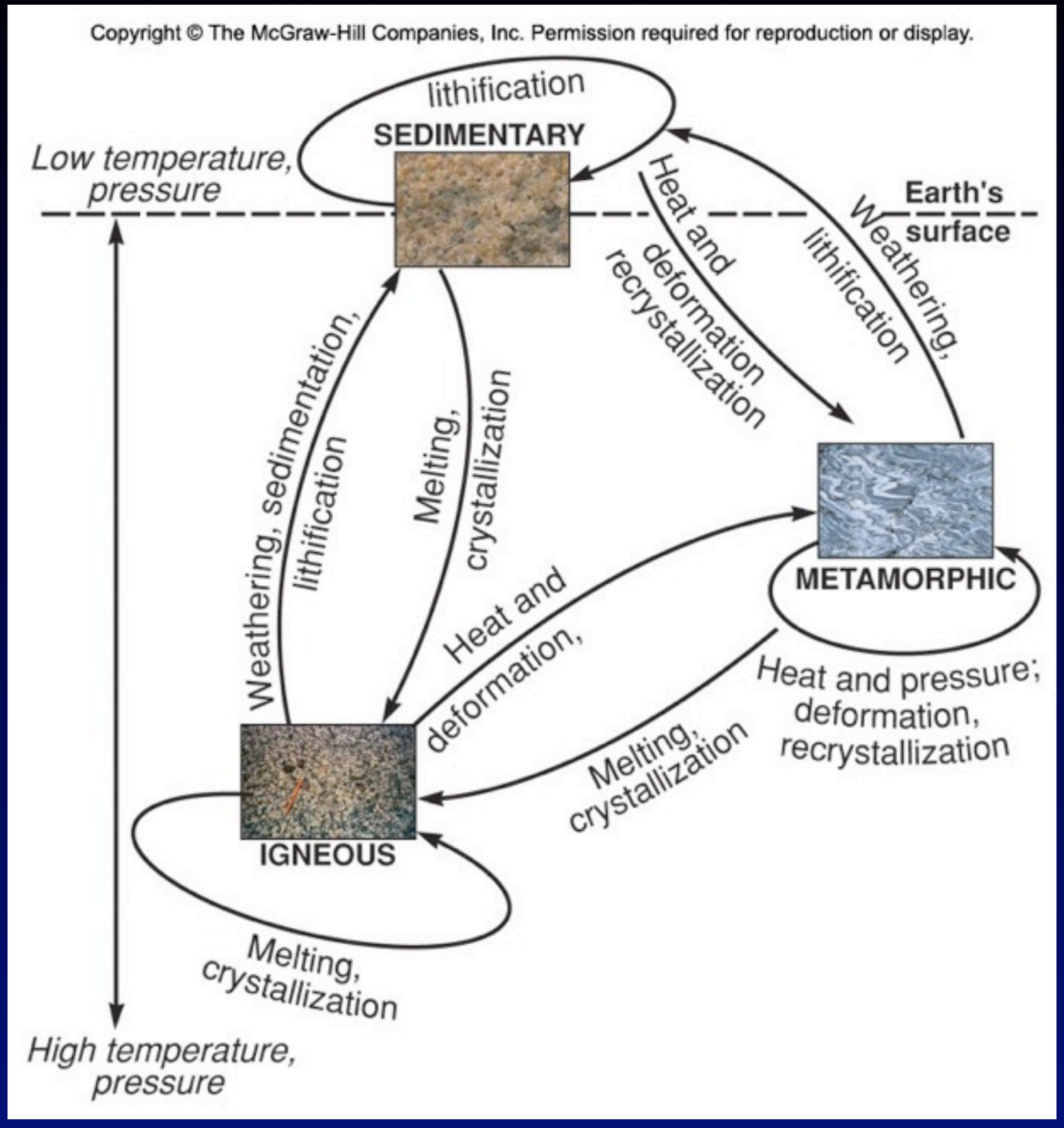
Rock Cycle: Formation

Unit Two

Rock Types

- Rock Cycle - cycle of creation, destruction, and metamorphosis
  - Three major rock classifications:
    - Igneous (latin word meaning “fire”)
    - Sedimentary
    - Metamorphic

Rock Cycle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lithification
SEDIMENTARY
Low temperature, pressure
Earth's surface
Heat and deformation recrystallization
Weathering, lithification
Weathering, sedimentation, lithification
Melting, crystallization
Heat and deformation,
METAMORPHIC
Heat and pressure; deformation, recrystallization
Melting, crystallization
IGNEOUS
Melting, crystallization
High temperature, pressure

Igneous Rocks

- ***Most common*** type of rock in Earth's crust.
  - ***Solidified from magma*** extruded onto the surface from volcanic vents
    - Quick cooling of magma produces fine-grained rocks.
      - Basalt

    - Slow cooling of magma produces coarse-grained rocks.
      - Granite

Metamorphic Rock

- ***Pre-existing rocks modified by heat, pressure, and chemical agents***
  - Chemical reactions can alter both the composition and structure of rocks as they are metamorphosed.
    - Marble (from limestone)
    - Quartzite (from sandstone)
    - Slate (from mudstone and shale)

Weathering

- Mechanical weathering - physical break-up of rocks into smaller particles without a change in chemical composition

- Chemical weathering - selective removal or alteration of specific components that leads to weakening and disintegration of rock
  - Oxidation
  - Hydrolysis

Sedimentation

- Sedimentation - deposition of particles of rock transported by wind, water, ice and gravity until they come to rest in a new location

- Lithification - (from the Greek word lithos meaning 'rock') is the process in which sediments compact under pressure, expel connate fluids, and gradually become solid rock

Sedimentary Rock

- ***Deposited materials that remain in place long enough, or are covered with enough material for compaction, may again become rock.***
- Examples: Sandstone, shale

- Also can be formed from crystals that precipitate out of, or grow from, a solution.
- Example: Halite

Sedimentary Rock

- The sedimentary rock of Bryce Canyon National Park has been carved by erosion into tall spires.

Soil

Unit Two

Soils are Complex Ecosystems

- Soil is a renewable resource that develops gradually through the weathering of rocks and the accumulation of organic material.
- The accumulation of topsoil is a very slow process. Under the best circumstances it accumulates at a rate of about 1 mm/year.
- With careful management, soil can be replenished and renewed indefinitely.

6 Components of Soil

- Soil is a marvelous, complex substance; an entire ecosystem that is hidden to most of us. In general it has 6 components:

  - Sand and gravel (inorganic)
  - Silt and clay (inorganic)
  - Dead organic material (organic)
  - Soil fauna and flora (organic)
  - Water (inorganic)
  - Air (inorganic)

Variation in Soil Composition

- Variation in the 6 components of soil can produce and almost infinite variety of soil types.

- ***Soil texture, the amount of sand, silt and clay in the soil, is an important characteristics of soils.***

- Loam soils are considered best for agriculture because they are a mixture of sand, silt and clay.

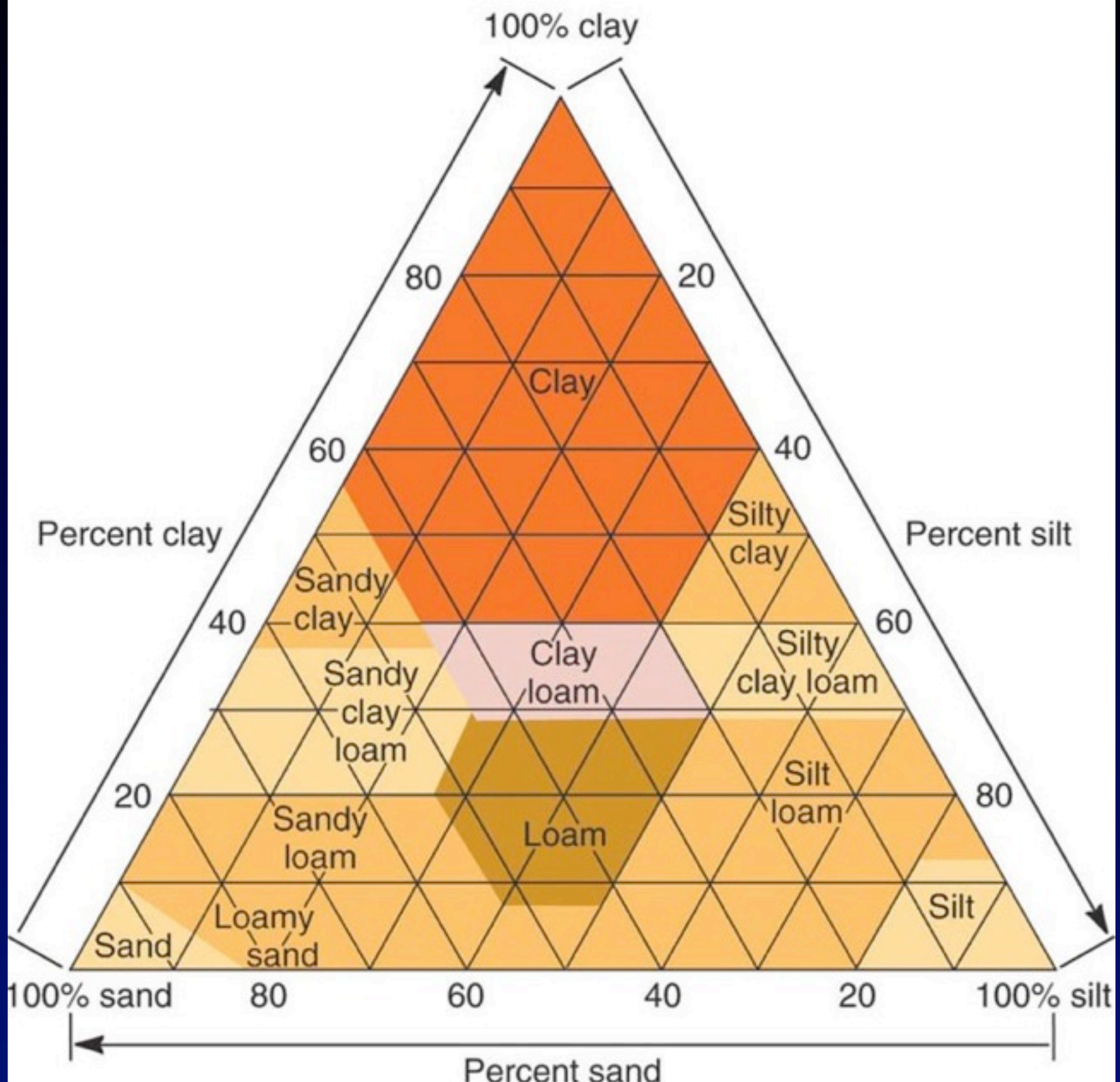
- Local soil types depend on a variety of factors: climate, slope, biological activity as well as parent material.

Components of Soil

- Sand and gravel
  - (relatively larger mineral particles, lots of oxygen, little water)
- Silt and clay
  - (very small mineral particles, holds water well due to flat surface and ionic charges but little space for oxygen)

- In Summary:
  - Sand=large particles
  - Silt=small particles

Soil Texture Pyramid



A Soil Comparison

- Brazilian tropical soils are deeply weathered red clays which have little organic material. They hold few nutrients and water .

- The rich, black soils of the Midwestern US are rich in nutrients and organic material and contain a mixture of sand, silt and clay to hold moisture well

Grassland vs. Tropical Rainforest Soils

(a) (b)

Courtesy USDA/NSCC

Soil Fauna Determine Fertility

- Soil bacteria, algae and fungi decompose leaf litter making recycled nutrients available to plants.
  - ***humus***- sticky, brown, insoluble residue from the bodies of dead plants and animals (decaying organic matter) that serves as a major source of plant nutrients
- A single gram of soil can contain hundreds of soil bacteria and 20 meters of tiny fungal strands.

- Tiny worms and nematodes process organic material and create air spaces as they burrow.
- Larger insects, spiders and mites loosen and aerate the soil as well.

Soil Ecosystems

Soil Horizons

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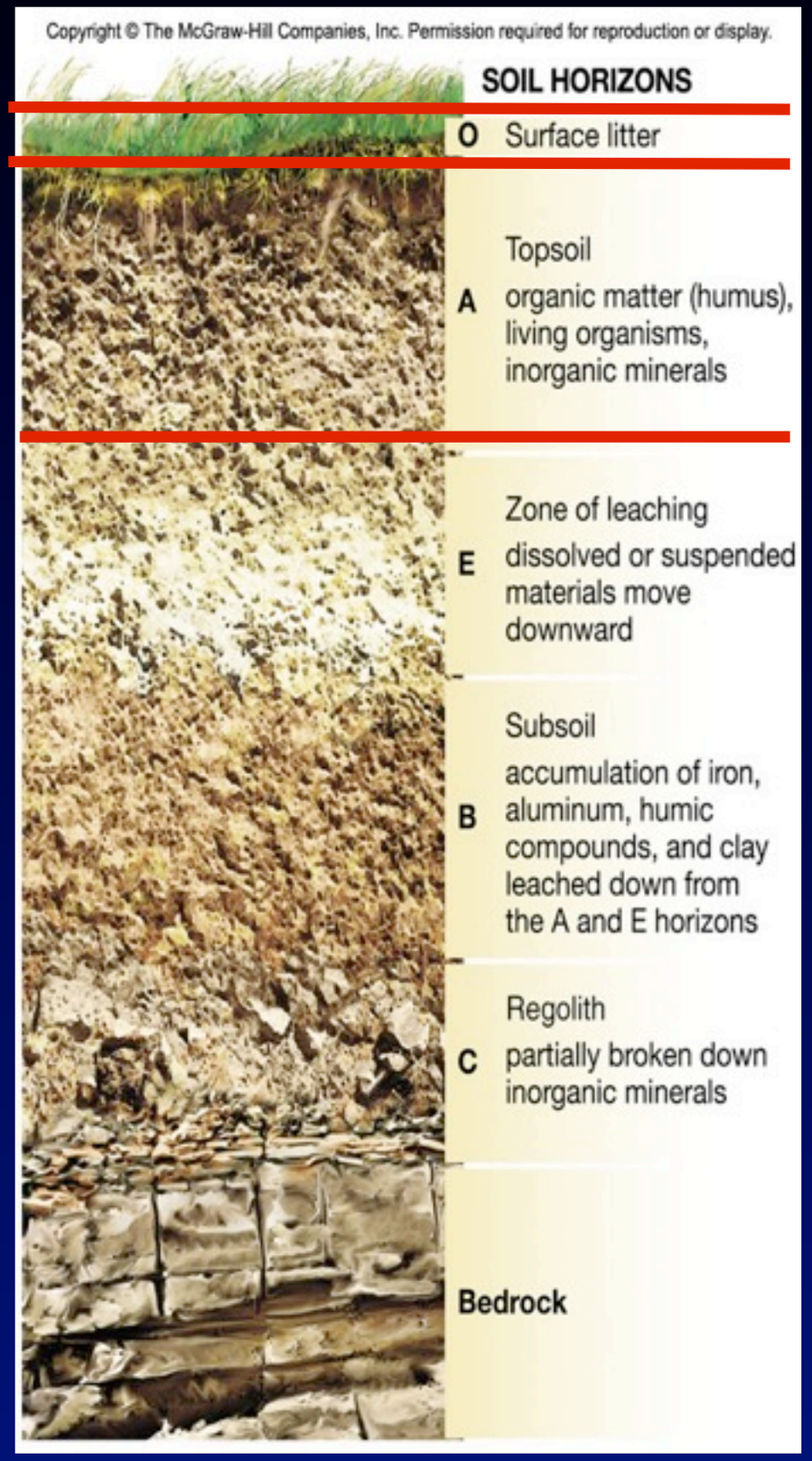
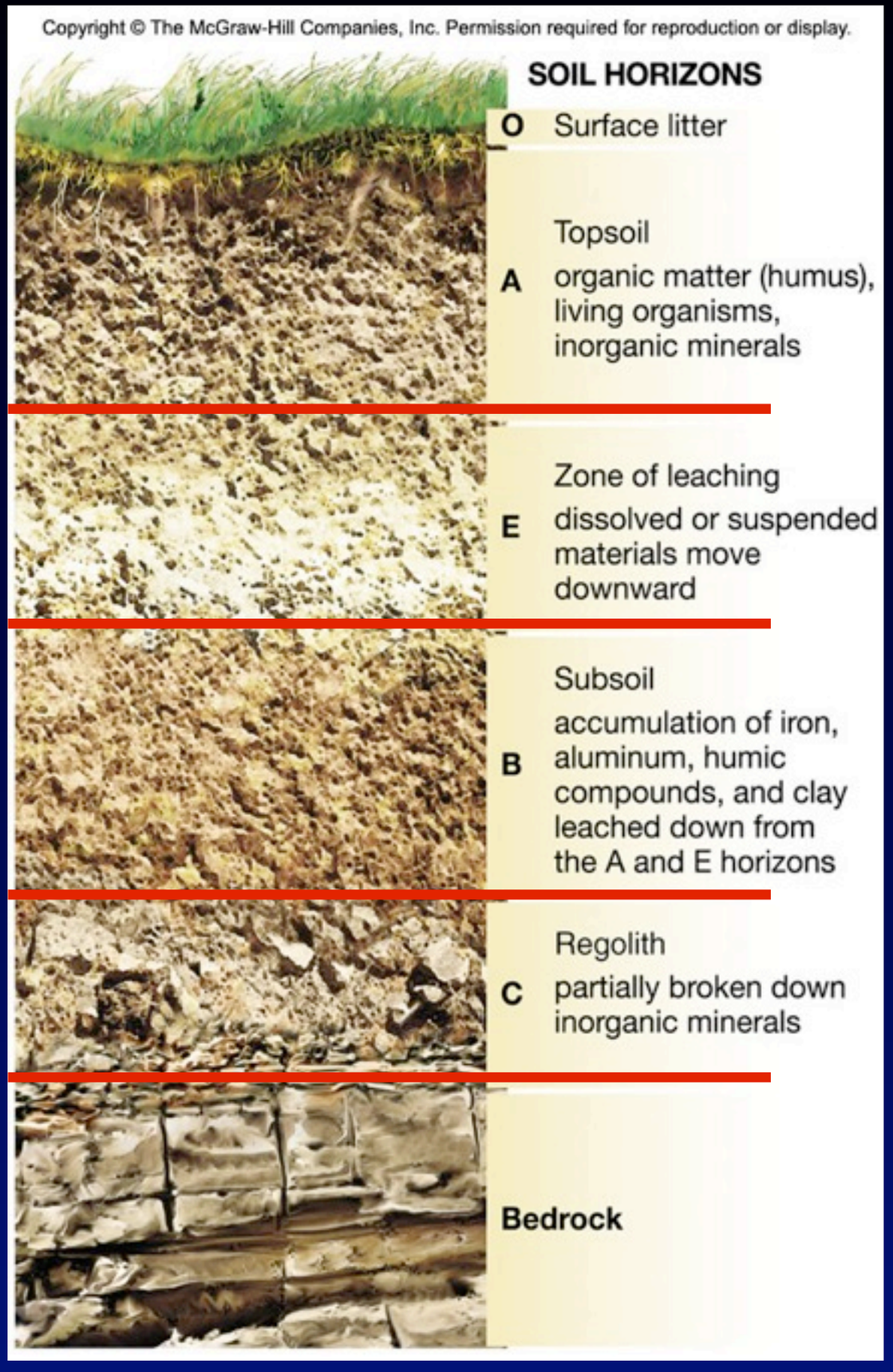
Soils are Layered

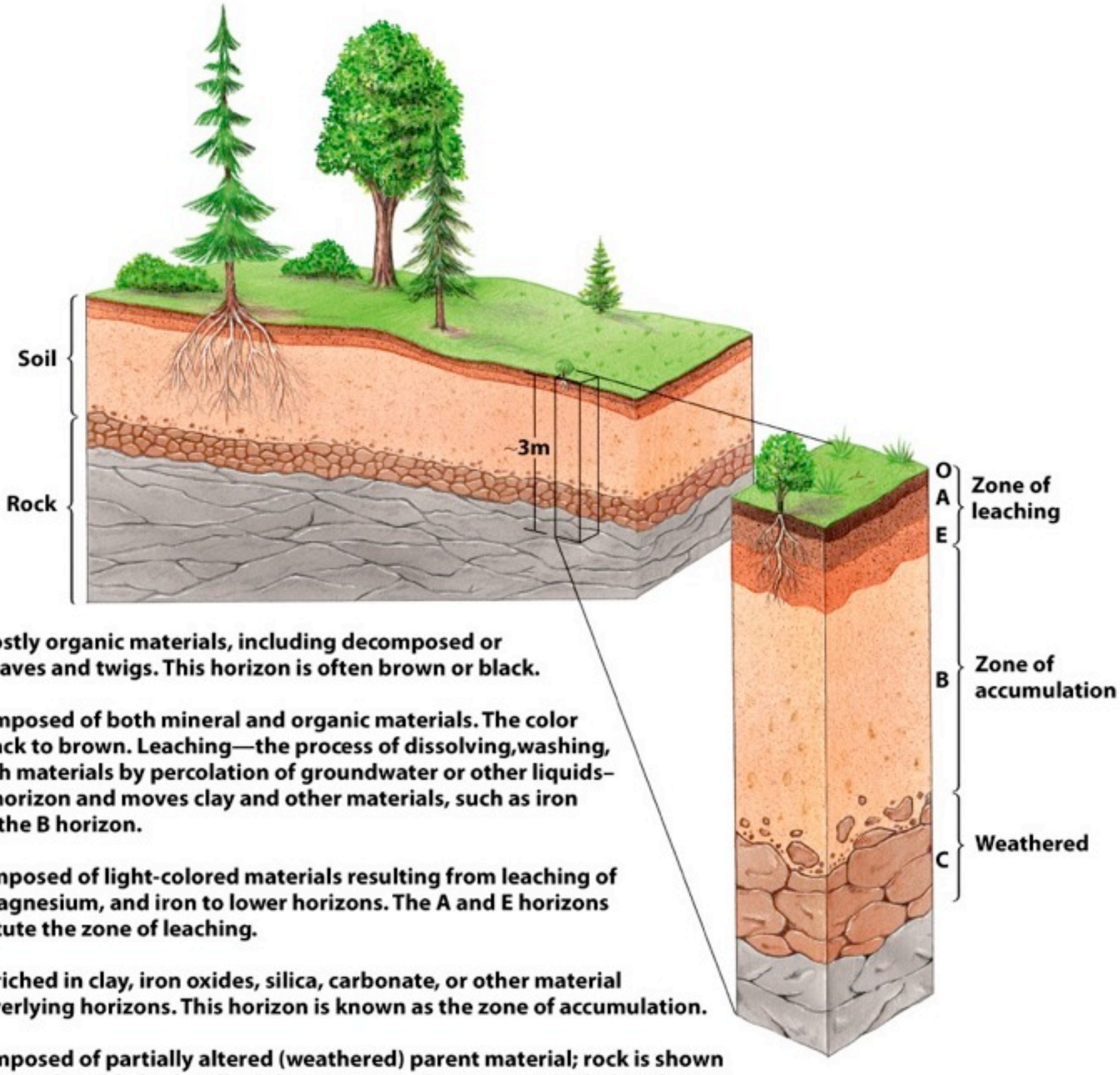
- Soils are stratified into horizontal layers called soil horizons.
  - Horizons taken together make up soil profile.
    - O Horizon (Organic litter layer)
      - Leaf litter, most soil organisms and partially decomposed organisms
    - A Horizon (Top soil)
      - Mostly mineral particles mixed with organic material
      - Supports crops



Soil Profiles

- E Horizon (washed out)
  - Depleted of soluble nutrients
- B Horizon (Subsoil)
  - Often dense texture from accumulating nutrients
- C Horizon or regolith (Parent Material)
  - Weathered rock fragments with little organic material
- D Horizon (Bedrock, impenetrable)





Horizons

O **Horizon is mostly organic materials, including decomposed or decomposing leaves and twigs. This horizon is often brown or black.**

A **Horizon is composed of both mineral and organic materials. The color is often light black to brown. Leaching—the process of dissolving,washing, or draining earth materials by percolation of groundwater or other liquids–occurs in the A horizon and moves clay and other materials, such as iron and calcium, to the B horizon.**

E **Horizon is composed of light-colored materials resulting from leaching of clay, calcium, magnesium, and iron to lower horizons. The A and E horizons together constitute the zone of leaching.**

B **Horizon is enriched in clay, iron oxides, silica, carbonate, or other material leached from overlying horizons. This horizon is known as the zone of accumulation.**

C **Horizon is composed of partially altered (weathered) parent material; rock is shown here, but the material could also be alluvial in nature, such as river gravels, in other environments. This horizon may be stained red with iron oxides.**

R **Unweathered (unaltered) parent material. (Not shown)**

Soil: Erosion

Unit Two

Our Eroding Soil

- When land cleared of its natural vegetation, the soil begins to lose its fertility
  - Physical erosion

- Became a national issue in the US in the 1930s
  - Intense plowing + drought
  - Loosened soil blow away

Our Eroding Soil

- The land that became the Dust Bowl had been prairie
  - Deep rooted grasses that held soil in place
  - After plowing soil exposed to elements
- When original vegetation is cleared soil changes
  - Crops harvested and removed, less organic matter returning to soil
  - Soil exposed to sunlight which speeds rate of decomposition

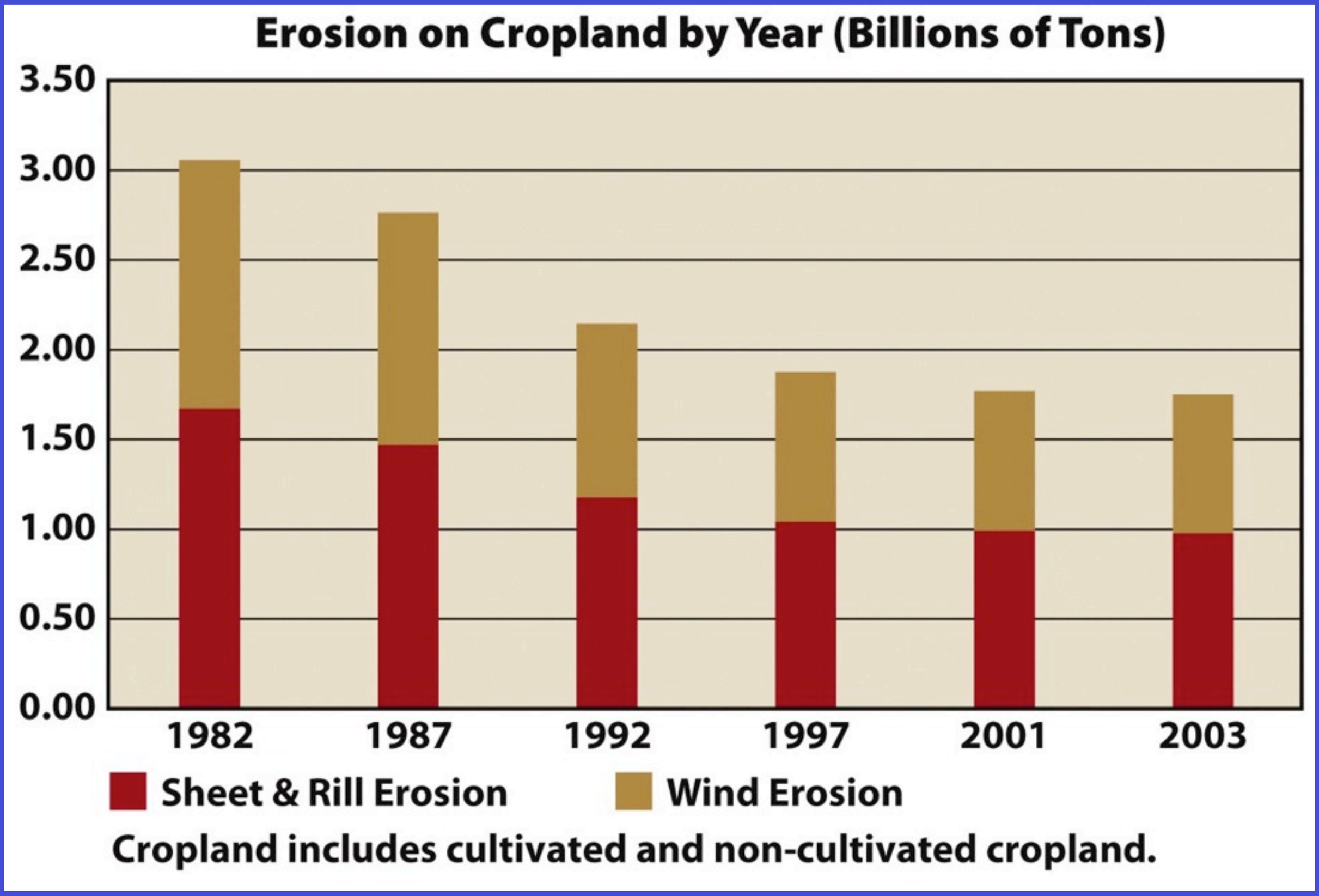
Our Eroding Soil

- Traditionally decline in soil fertility combated using organic fertilizers
  - Animal manure

- In the 20th century crop production increased
  - Chemical or artificial fertilizers
  - Add nitrogen and phosphorous to the soil

Our Eroding Soil

- Since WWII mechanized farming has seriously damaged land
  - –> 1 billion hectares
  - –In US 1/3 of topsoil has been lost


Erosion on Cropland by Year (Billions of Tons)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1982
1987
1992
1997
2001
2003
Sheet & Rill Erosion
Wind Erosion
Cropland includes cultivated and non-cultivated cropland.

Erosion can to lead to Desertification

(a) Sheet and rill erosion

Photo by Lynn Betts, courtesy of USDA
Natural Resources Conservation Service

(b) Gullying

Photo by Jeff Vanuga, courtesy of USDA
Natural Resources Conservation Center

(c) Wind erosion and desertification

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Where Eroded Soil Goes

- A lot of it travels down streams and rivers
  - Deposited at their mouths
    - Fill in water ways
    - Damage fisheries and coral reefs

- Sedimentation has chemical effects
  - Enrichment of waters, eutrophication
  - Transport of toxic chemical pesticides

Soil: Other Problems

Unit Two

Desertification

- Earth has 5 natural warm desert regions
  - Primarily between 15° and 30° north and south of the equator
- Based on climate alone 33% of Earth's land area should be desert
  - 43% of land is desert
  - Addition area due to human activities

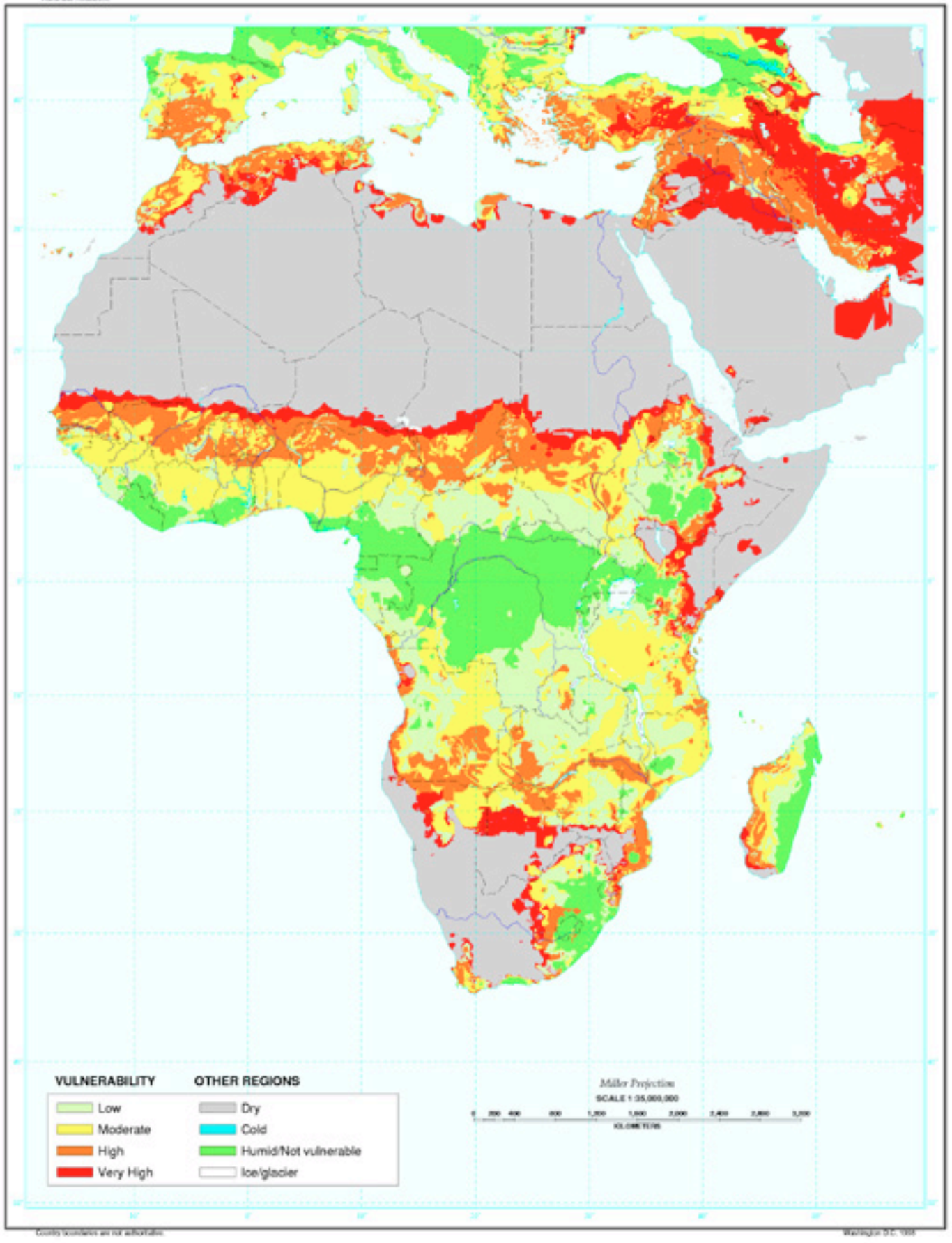
Desertification

- ***Desertification*** – the deterioration of land in arid, semiarid, and dry sub humid areas due to changes in climate and human activities (poor land management).
- Serious problem that affects 1/6 of world population (1 billion people)

Desertification

- Deserts occur naturally where there is too little water for substantial plant growth.
  - The warmer the climate the greater the rainfall needed to convert an area from desert to non-desert
  - The crucial factor is available water in the soil for plant use
  - Factors that destroy the ability of a soil to store water can create a desert

Desertification vulnerability of Africa

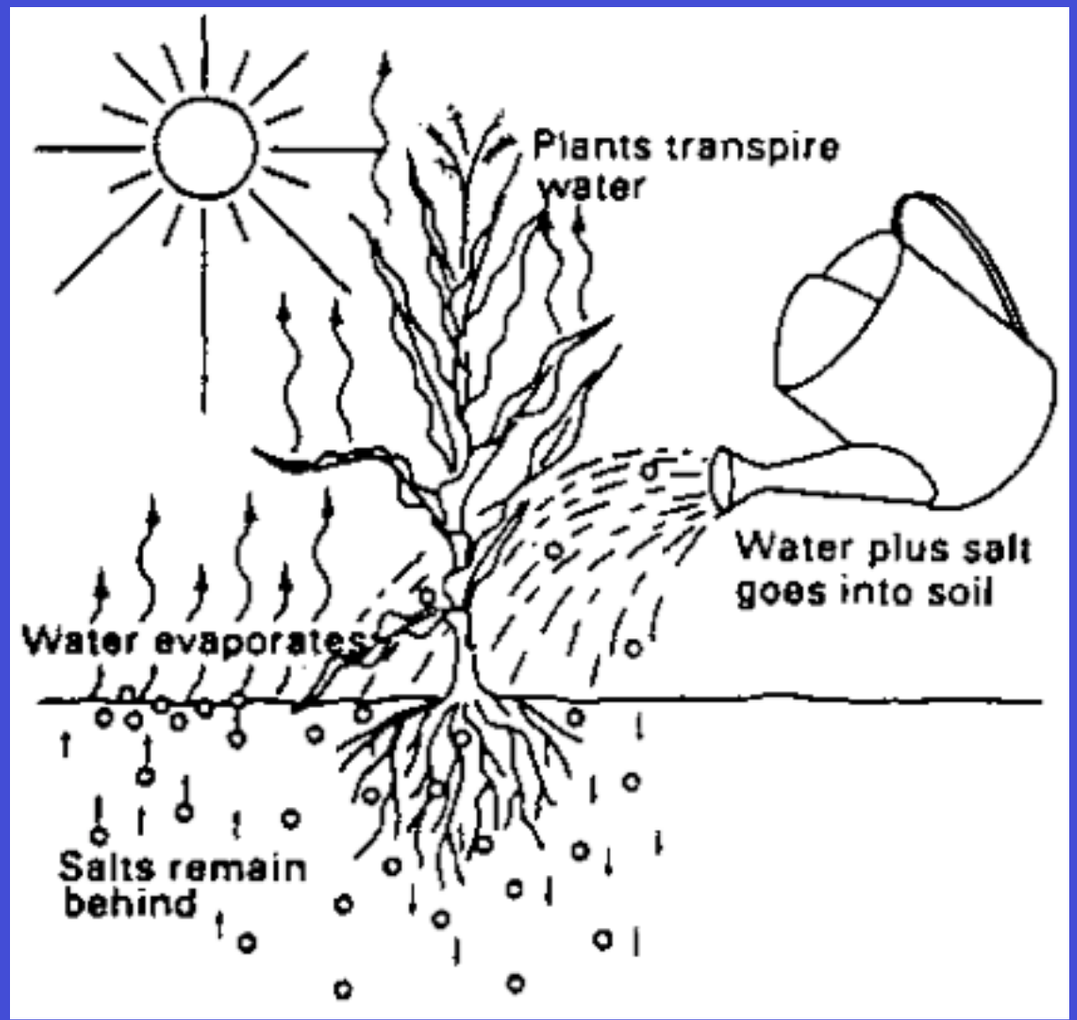


What Causes Desertification

- The leading cause of desertification are bad farming practices.
  - Failure to use contour plowing
  - To much farming
  - Overgrazing
  - Conversion of rangelands to croplands in marginal areas
  - Poor forestry practices

Other Causes of Desertification

- Desert like areas can be created anywhere by poisoning of the soil
  - World wide chemicals account for 12% of soil degradation
  - Irrigation in arid lands can cause salts to build up to toxic levels



Grazing on Rangelands

- Almost half of the Earth's land area is used as rangeland
  - 30% of Earth's land area is arid rangeland
- Arid rangeland easily damaged especially in time of drought
- Steams and rivers also damaged
  - Trampling banks and fecal matter

Carrying Capacity of Grazing Lands

- ***Carrying capacity-***
  - –the maximum number of species per unit area that can persist w/o decreasing the ability of that population or its ecosystem to maintain that density in the future.
- When the carrying capacity is exceeded, the land is overgrazed.

Carrying Capacity of Grazing Lands

- Overgrazing
  - Slows the growth of vegetation
  - Reduces the diversity of plant species
  - Leads to dominance by plant species that are relatively undesirable to the cattle
  - Hastens loss of soil by erosion
  - Subject the land to further damage from trampling

Traditional and Industrial Use of Grazing and Rangelands

- In modern industrialized agriculture
  - Cattle initially raised on open range
  - Then transport to feed lots
  - Major impact is local pollution from manure

- Traditional herding practices
  - Damage land through overgrazing
  - Impact varies depending on density relative to rainfall and soil fertility

Soil: Conservation

Unit Two

Making Soils Sustainable

- Soil forms continuously
  - But very slowly
  - 1mm of soil formation takes 10-40 years

- To be truly sustainable soil lost should equal amount of new soil produced

Contour Plowing

- Land is plowed perpendicular to the slopes and as horizontally as possible.
  - One of the most effective ways to reduce soil erosion
  - Also uses less fuel and time

Photo by Lynn Betts, courtesy of USDA Natural Resources Conservation Service

Contour Plowing

Terracing

-A terrace is an embankment constructed perpendicular to a slope

-Terraces are often built following the curvature of the land

-Terraces reduces erosion by reducing the slope length and thereby reducing water runoff velocity

-Terraces increases water infiltration and reduces runoff

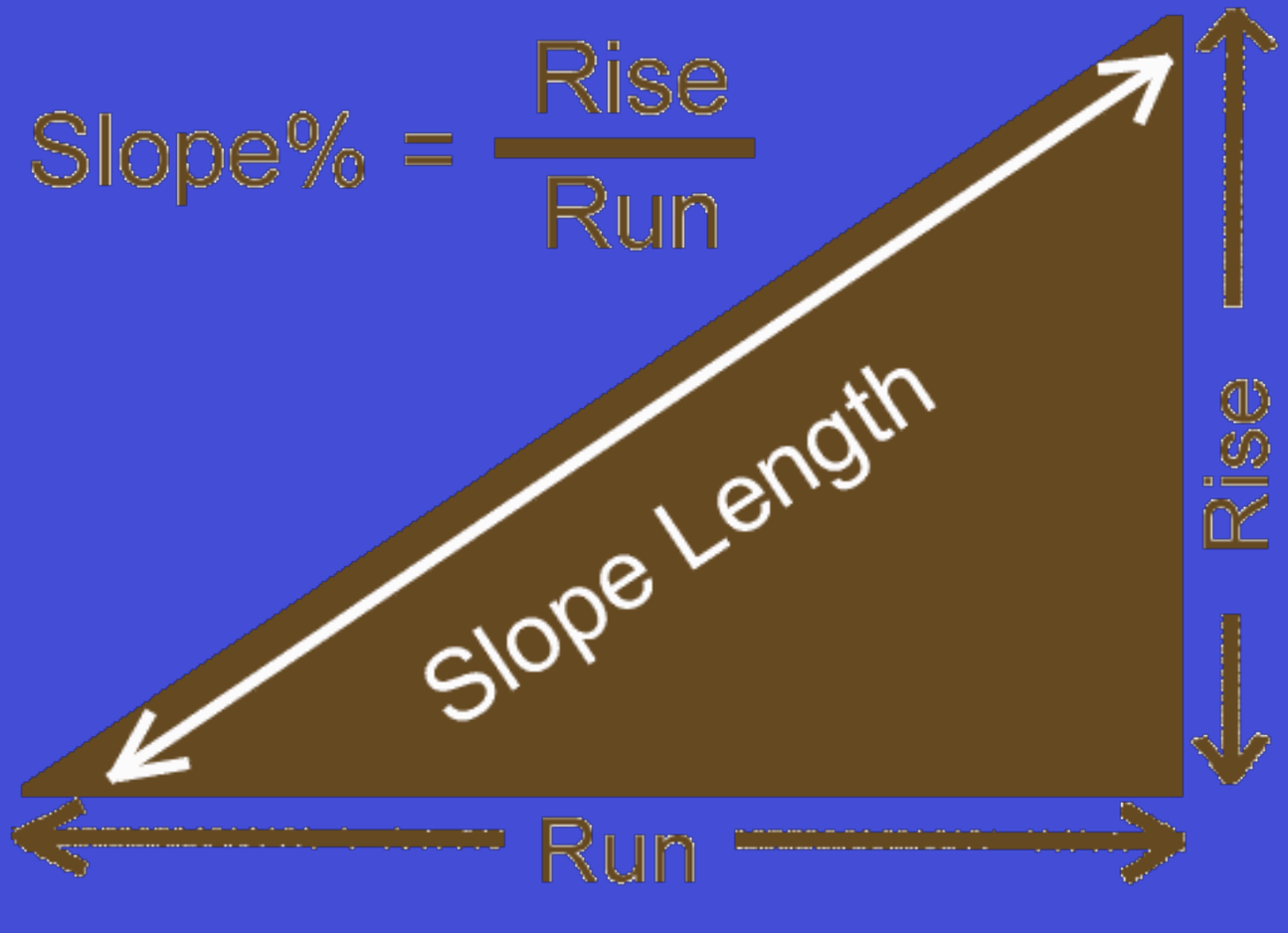
-Excess water collected on the terraces drains either through a buried underground pipe system

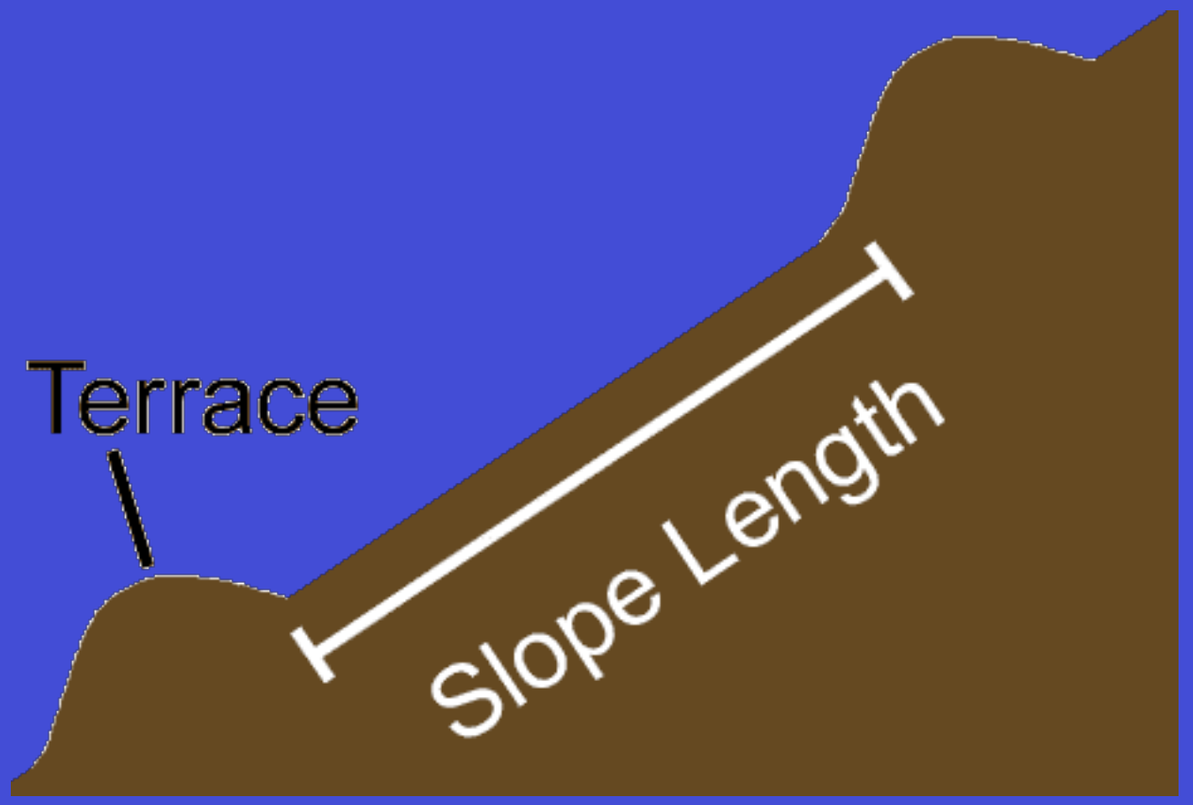
-Terrace building can be quite costly because it involves moving large quantities of soil and land grading to change the slope length.

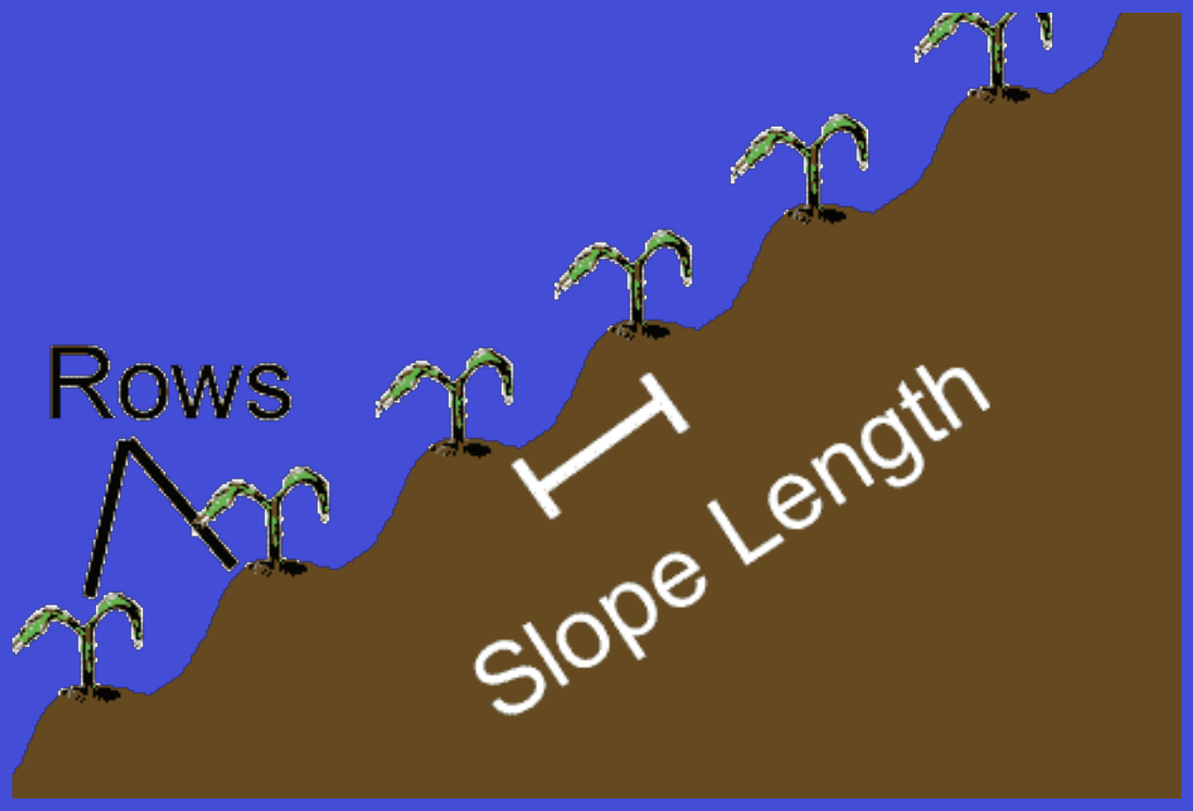
Terracing

© William P. Cunningham

Slope% = Rise / Run







No-Till Agriculture

- Involves not plowing the land, using herbicides and integrated pest management to keep down weeds, and allowing some weeds to grow.
  - The goal is to suppress and control weeds but not eliminate them at the expense of soil conservation
  - Additional benefits: reduces soil erosion, reduces pesticide use, reduces soil compaction and it reduces energy consumption and thus the release of CO_2

Conventional Tilling


Cross Wind
Strip Cropping

Surface Roughening and Maintaining Stable Aggregates

Vegetation or
Vegetative Residue

Residue Management

Permanent Vegetative Cover

Pasture & Hay Planting

Conservation Cover

Critical Area Planting

Preventing Desertification

- First step is detection of symptoms
  - Lowering of water table
  - Increase in the salt content of soil
  - Reduced surface water
  - Increased soil erosion
  - Loss of native vegetation
- Achieved by monitoring

Preventing Desertification

- Next step
  - Proper methods of soil conservation, forest management and irrigation
- Good soil conservation includes
  - Use of wind breaks
  - Reforestation
  - ***Green Manure-*** a type of cover crop grown primarily to add nutrients and organic material to the soil.
    - suppresses weeds, decreases erosion and compaction