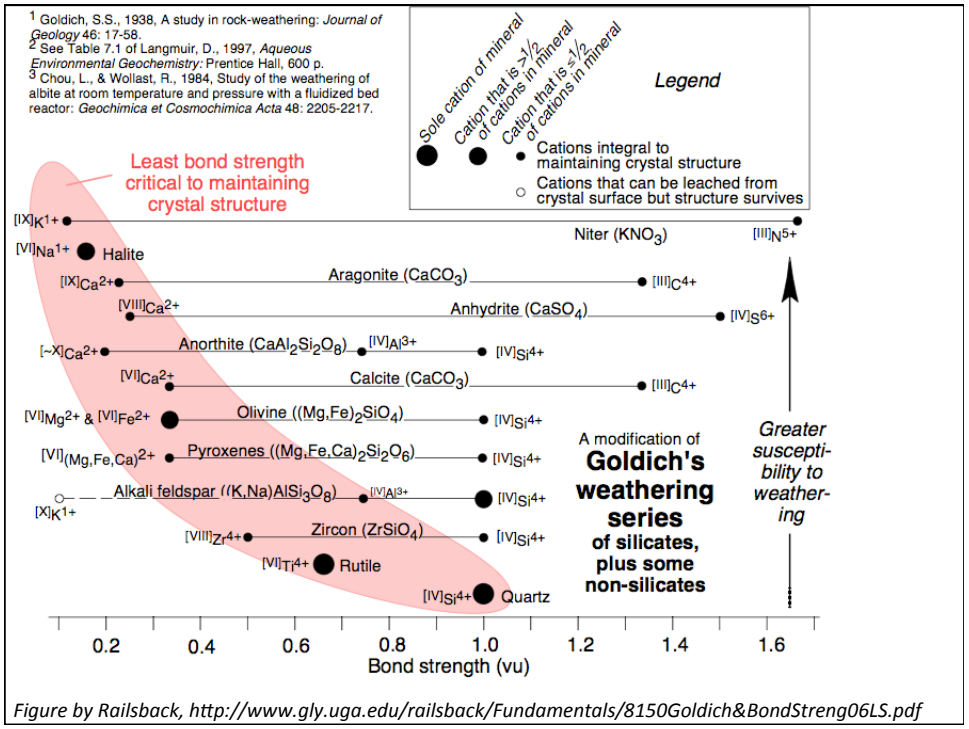
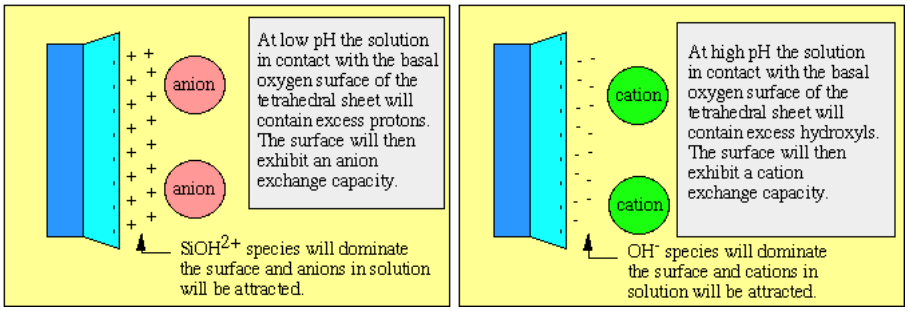
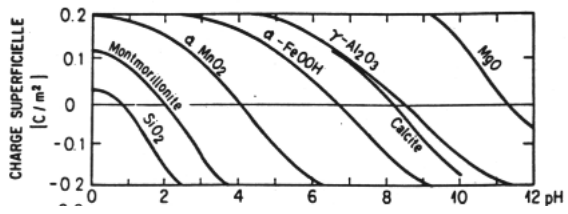


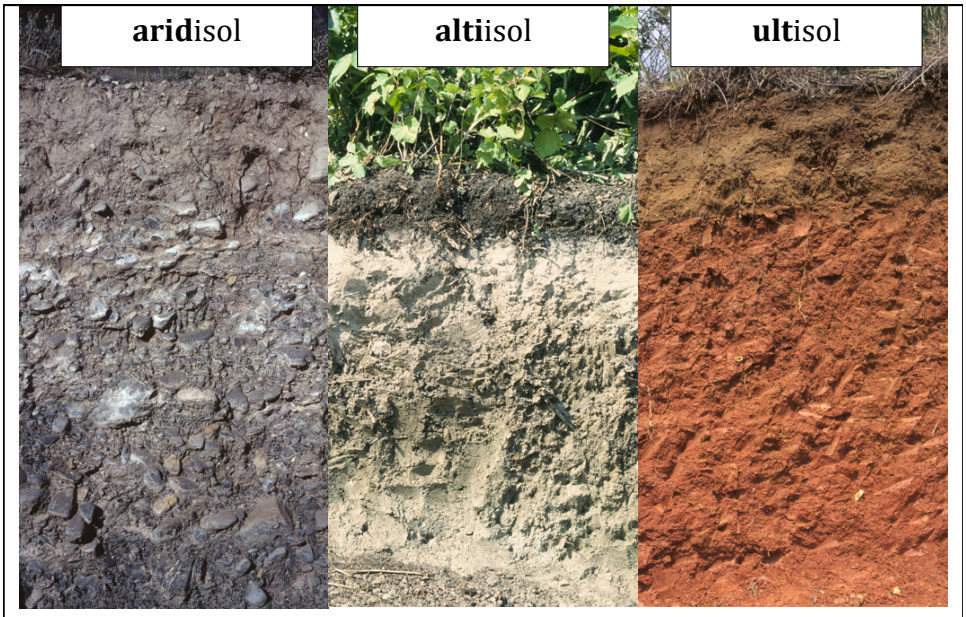
Figure by Railsback, http://www.gly.uga.edu/railsback/Fundamentals/8150Goldich&BondStreng06LS.pdf

Surface charges and adsorbtion



Borrowed from Paul Schroeder, Uga
http://clay.uga.edu/courses/8550/





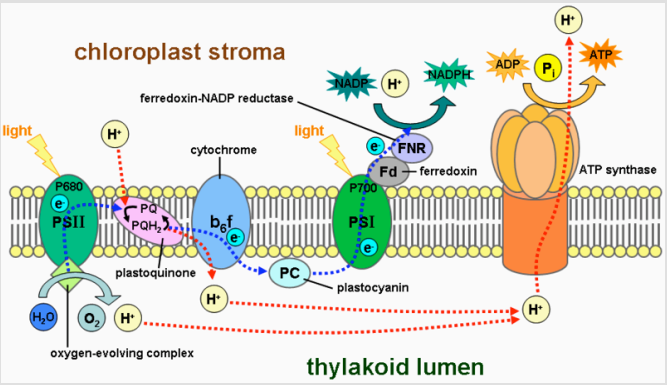
Low w/r and/or T | Medium w/r and/or T | High w/r and/or T

Photosynthesis

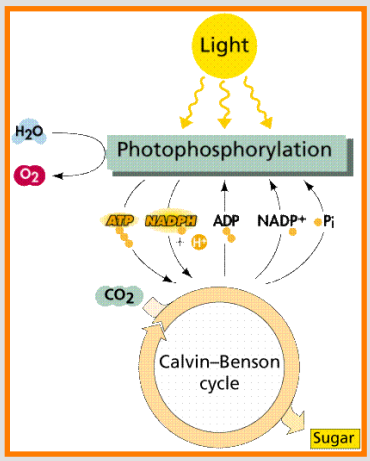
- The biochemical process that transfers carbon from its oxidized form to its reduced form

$$6CO_2 + 6H_2O + h\nu \rightarrow C_6H_{12}O_6 + 6O_2\uparrow$$

- Actual reaction is much more complicated!



Two Stages of Photosynthesis



- Light Reactions: Light energy is utilized by chlorophyll molecules to split water molecules
  - electrons from this process are used to create two high-energy phosphate compounds, NADPH and ATP
- Dark Reactions: The phosphate compounds are then used by enzymes (*e.g.* RUBISCO) to reduce CO_2 to CH_2O

CO_2 Assimilation Pathways

- Three metabolic pathways used by plants to reduce CO_2 to carbohydrate
  - C_3 -- constitute the bulk of global plant biomass, most higher-plants use the C_3 pathway
  - C_4 -- generally are non-woody plants (*i.e.* grasses) that adapted to warm, arid climates
  - CAM (Crassulacean Acid Metabolism)-- common mode in succulents and epiphytes
- C_4 plants are capable of higher CO_2 uptake rates than their C_3 counterparts
  - Important when considering carbon isotope fractionation

Primary Productivity

- *Gross* Primary Productivity (GPP): amount of carbon that has been processed from CO_2. Usually expressed in g $C/m^2/yr$

Plant Respiration

- Oxygen is consumed through metabolic activity in the mitochondria of eukaryotes
- *Net* Photosynthesis: fixation of carbon in excess of the simultaneous release of CO_2 by plant metabolism

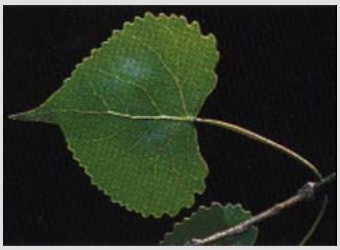
Net Primary Productivity

- Net Primary Productivity (NPP): amount of carbon that has been sequestered by plants over a specified interval of time, which is made available to other trophic levels
  = *Gross Primary Productivity (GPP) - Plant Respiration (R_P)*
- Carbon losses due to decomposition of organic material in the soil are not part of the NPP calculation
- Typical NPP ≈ GPP/2

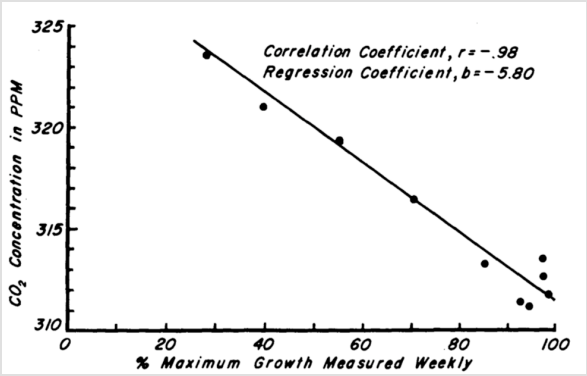
Field estimates of NPP

Need to account for:

- Wood vs. foilage production
- Aboveground vs. belowground production
- Litterfall & root turnover
- Grazing, etc. by herbivores



Relating NPP to pCO_2



Plant growth vs. pCO2 in the arctic summer. Johnson and Kelley, 1970

- Atmospheric CO_2 gradient between the tropospheric background and in the plant canopy changes as a result of CO_2 uptake by vegetation and respiration
- This gradient averaged over an interval of time is related to the net carbon uptake by the vegetation

NPP from leaf area

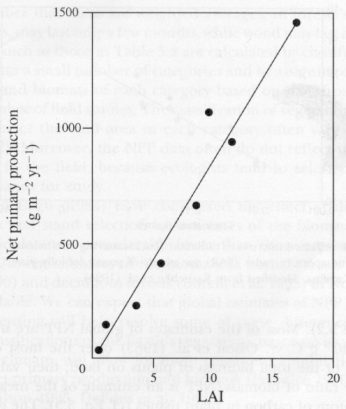


Figure 5.8 Net primary production is directly related to leaf-area index for forests in the northwestern United States. Modified from Gholz (1982).

- LAI = Leaf Area Index

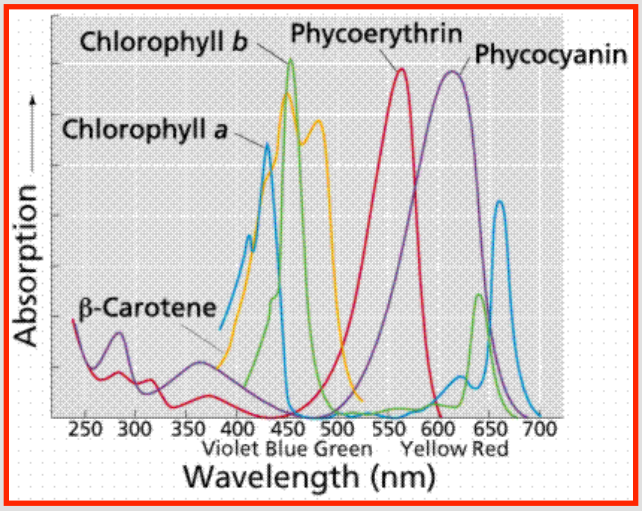
the area of leaves above a square meter of ground surface (m^2/m^2)

Estimating leaf area (NPP) remotely

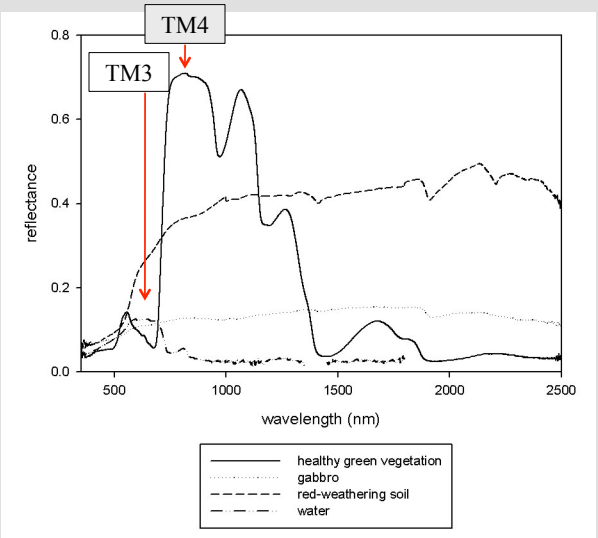
Plate 1 Normalized Difference Vegetation Index (NDVI) for June 1982 as obtained from the Advanced Very High Resolution Radiometer on the NOAA satellite. Note that the greatest vegetation density is colored white and blue, whereas green and yellow indicate lower leaf area. The Northern Hemisphere is in mid-summer. From NASA, 1987, Moderate-Resolution Imaging Spectrometer, Instrument Report, Washington D.C.

- Passive surface measurements of color reflectance by LANDSAT and AVHRR
- Chlorophyll reflects strongly in the green (~500nm) and infrared (800-1200nm) wavelengths
- Absorbs in blue, red

Light Absorption by Photosynthetic Pigments



"Seeing" leaves



Spectra of vegetation, rocks and soils. D. Leverington (Texas Tech)

http://www.webpages.ttu.edu/dleverin/hyperspectral/hyperspectral_imaging.html

Vegetation reflects more sunlight in TM4, relative to TM3 than soil or rocks.

Hypothesis:
TM4/TM3 ⇧ as chlorophyll ⇧

Stronger signal → more leaves

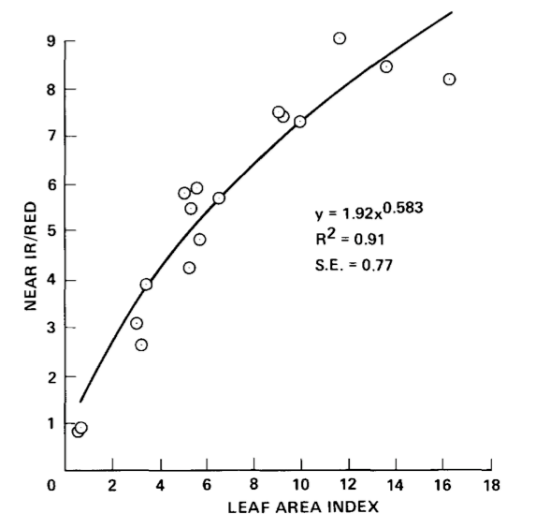


FIGURE 8. Relationship between the atmospherically corrected near IR/red ratio and the LAI of the forest stands.

Correlation between TM4/ TM3 and leaf area index in a conifer forest
Peterson et al. 1987

Estimation of Biomass from Synthetic Aperture Radar (SAR)

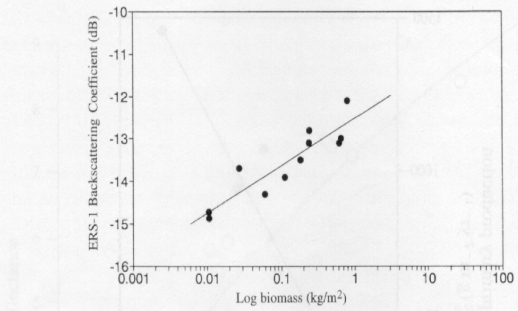


Figure 5.9 The reflected microwave radiation (backscattering coefficient) measured by an airborne synthetic aperture radar (SAR) for stands of young loblolly pine (*Pinus taeda*) in central North Carolina. Modified from Kasischke et al. (1994).

- Microwave emitter mounted on an aircraft
- Live, woody vegetation absorbs and reflects microwave radiation as a function of the height and volume of water-filled tissue
- These data can be used to estimate biomass

Global Estimates of Terrestrial Biomass

- Houghton and Skole (1990) estimate total terrestrial biomass at 558.8 x 10^{15} g C

Highest Biomass Values			
Mean Plant Biomass (kg C / m^2)		**Total C in Vegetation (10^{15} g C)**	
Temperate Forest	8.0	Temperate Forest	73.3
Boreal Forest	9.5	Boreal Forest	143
Tropical Rain Forest	15.0	Tropical Rain Forest	156

Global Estimates of Total Terrestrial Net Primary Productivity

- Most estimates of total NPP are between 45 and 65 x 10^{15} g C/yr
  - most based on compilations from harvest data
- Houghton and Skole (1990) estimate total NPP at 60.2 x 10^{15} g C/ yr

Highest Net Primary Productivity Values			
Mean Net Prim. Production (g C/m^2/yr)		**Net Primary Productivity (10^{15} g C/yr)**	
Cultivated Land	760	Tropical Rain Forest	8.3
Tropical Rain Forest	800	Tropical Woodland and Savanna	11.1
Wetland	1300	Cultivated Land	12.1

What Controls Terrestrial Primary Production?

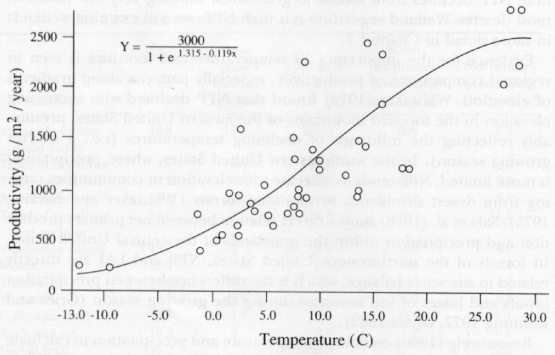


Figure 5.10 Relationship between NPP determined by harvest and mean annual temperature for 52 studies on various continents. From Lieth (1975).

- Temperature*
- Precipitation*
- Nutrient availability

General Trends in Terrestrial NPP

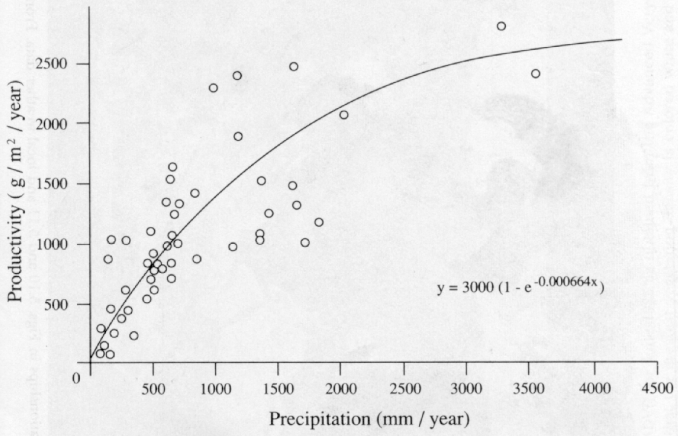


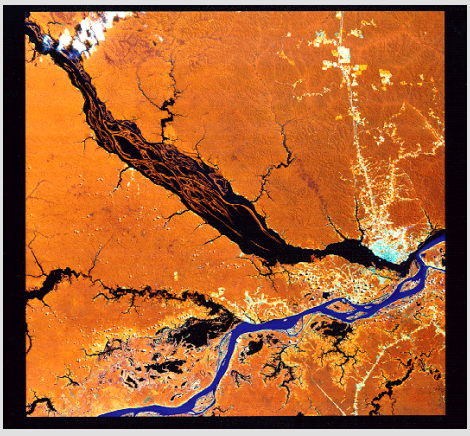
Figure 5.11 Relationship between NPP and mean annual precipitation for 52 locations around the world. From Lieth (1975).

- NPP increases with increasing precipitation

Controlling Factors in NPP

- Temperature and Precipitation considered most important factors on a global scale
- NPP can be predicted on a regional scale from precipitation and temperature
- Nutrient availability is more important locally or within individual regions

Human Activity -- Land Clearing



- Significant destruction of plant biomass, particularly in tropical areas
- Results in addition of CO_2 to the atmosphere
- 13% estimated decrease in terrestrial biomass from 1860 to 1980 (Houghton et al., 1983)

Regrowth

- Forest regrowth in some areas acts as a carbon sink
  - *e.g.* Southeastern U.S.
- Carbon storage by agricultural crops or forest regrowth, however, is generally less than original forest biomass

Productivity and Increasing Atmospheric CO_2

- Experimentally, increased ambient CO_2 concentrations cause enhanced rates of photosynthesis
  - reduction in water stress at stomata?
- Will this cause increased productivity across whole ecosystems??.....uncertain
- There is evidence, however, that some plants have already adapted to higher CO_2 concentration
  - more stomata on olive leaves in King Tut's Tomb (1327 B.C.)
- Warming ⇒ changes in biogeographic distribution of different vegetation types

Accumulation of Soil Organic Matter

- Primarily controlled by decomposition rates, rather than NPP
- Decomposition processes are very efficient
- Only a small fraction of the NPP is added to the long-term storage of organic matter in the soil

Total Global Storage of Carbon in Soils

- Highest mean soil organic matter in swamp areas = 68.6 kg C/m^2
- Highest total soil organic carbon in tropical forests = 255 mt C x 10^9
- Total Global C in soils estimated at 1456 x 10^{15} g C
  - Minor compared to that of anoxic marine sediments

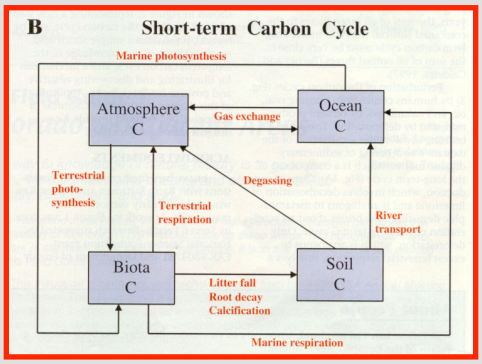
Carbon Loss from Soils Due to Human Activities

- Generally 20-30% soil organic matter is lost after the first ~20 years of cultivation
  - Oxidation
  - Erosion
- Large losses of soil organic matter when wetlands and peatlands are drained

Carbon Storage in the Terrestrial Environment

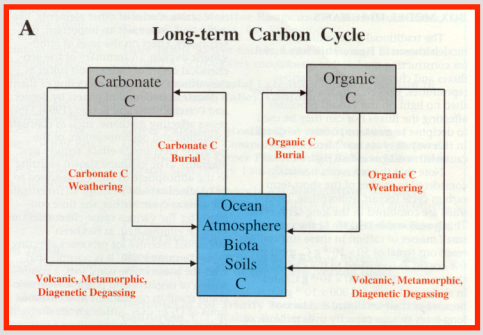
- Biota
  - living biomass
- Detritus
  - litterfall
  - root turnover
- Soil
  - resistant organic matter
  - carbonate

Short-term Carbon Cycle



- Exchange of carbon in the surficial system of the atmosphere, ocean, biota, and soils; exchange is relative rapid and operates on short time scales

Long-term Carbon Cycle



- Exchange of carbon between the surficial system and rocks; operates over millions of years

Chapter 5 Summary

- The terrestrial biosphere is an important component of the global carbon cycle
- Many techniques are used to estimate global terrestrial NPP
  - NPP of ~60 x 10^{15} g.C / yr
- Human activity has altered both terrestrial NPP and the long-term storage of soil organic matter
  - resulted in transfer of carbon to the atmosphere
- Many factors are involved in the effect of increased atmospheric CO_2 on the terrestrial carbon cycle
  - rates of photosynthesis
  - rates of soil decomposition
  - distribution of plant vegetation types