Forest Production Ecology

- Objectives
  - Overview of forest production ecology
    - C cycling
      - Primary productivity of trees and forest ecosystems

… ecologists and ecosystem managers are unlikely to achieve desired management objectives unless they are familiar with the distribution and movements of ***energy*** *that are responsible for the character and productivity of ecosystems under their management.* (Kimmins 2004)

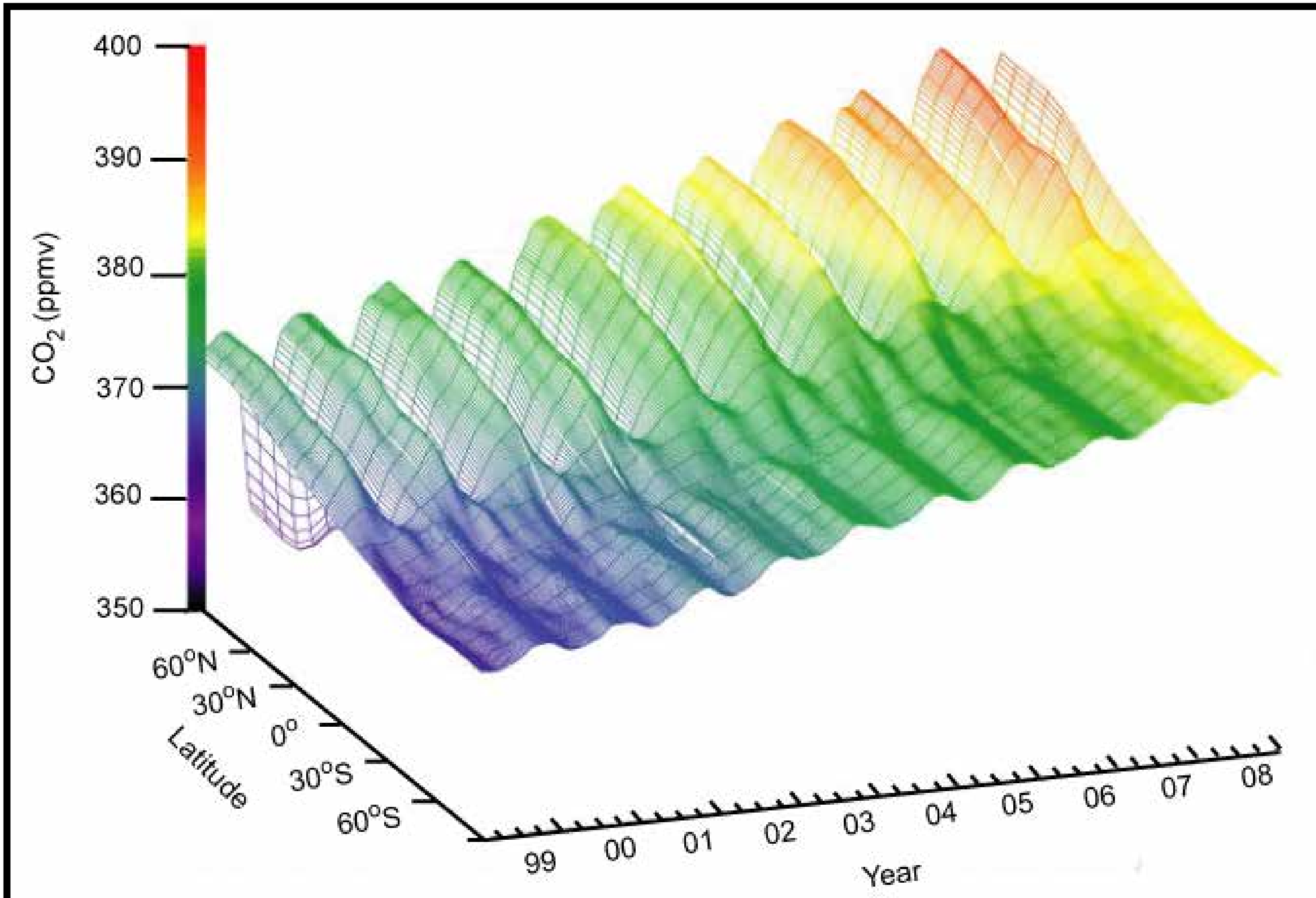
  - **First:** questions, take-home points, things you learned, etc. from reading assignment

Forest Production Ecology

- Why should you care about C cycling?
  - C is the energy currency of all ecosystems
    - Plant (autotrophic) production is the base of almost all food/energy pyramids
    - Underlies all ecosystem goods & services
  - Plant C cycling, to a large extent, controls atmospheric CO_2 concentrations (i.e., climate)
    - 3-4x as much C in terrestrial ecosystems as the atmosphere
    - Forests account for ~80% of global plant biomass and ~50% of global terrestrial productivity
  - C is fundamental to soil processes (i.e., SOM)
    - Belowground resources are a primary control over all ecosystem processes

Forest Production Ecology

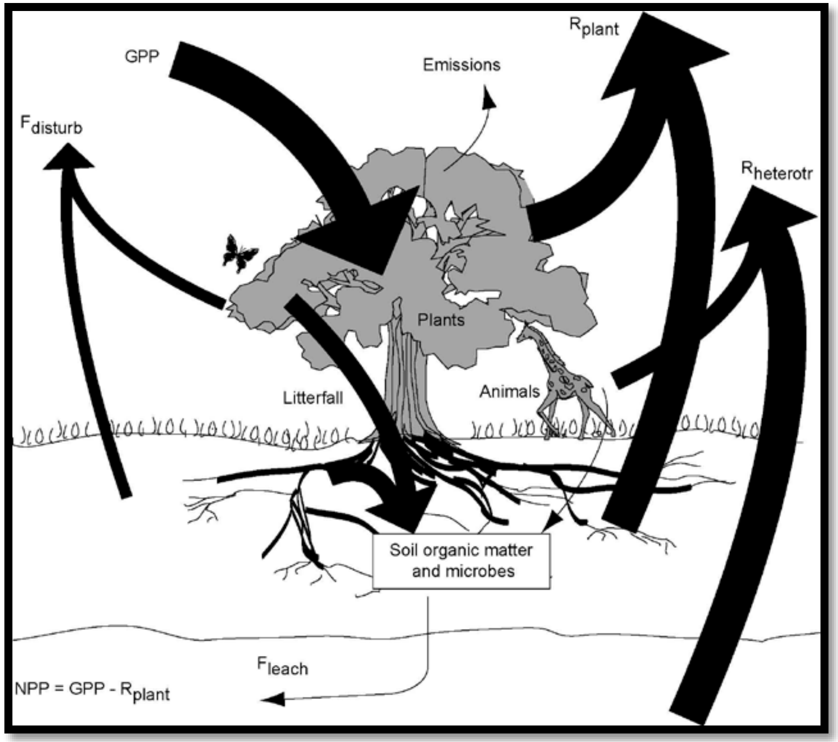
- Global Carbon Cycle ≈ "Breathing" of Earth



Forest Production Ecology

- C enters via photosynthesis
  1. Gross Primary Production (GPP)
     - Total C input via photosynthesis
  2. Accumulates in ecosystems (C pools/storage) as: (a) plant biomass; (b) SOM *& microbial biomass; or (c) animal biomass*
  3. Returned to the atmosphere via: (a) respiration (*R*; auto- or hetero-trophic); *(b) VOC emissions; or (c) disturbance*
  4. *Leached from or transferred laterally to another ecosystem*

The C Bank Account



Chapin et al. (2011)

Forest Production Ecology

- Keys to understanding biological C cycling
  1. Pools (storage) vs. fluxes (flows) of C
     - Live and dead (detrital) biomass
     - Above- and belowground
  2. Law of Conservation of Mass
     - *…mass can neither be created nor destroyed, although it may be rearranged in space, or…it may be changed in form*
     - Inputs = Outputs + DStorage
     - Inputs - Outputs = DStorage

Forest Production Ecology

- Keys to understanding biological C cycling

3. C that enters an ecosystem can change form, be stored, or be released back to the atmosphere
    - Stored C can move from one pool to another
4. C input (i.e., photosynthesis) controlled by LAI (resources) & length of growing season (climate)
5. C is primarily lost from ecosystems via:
    - *Short term*: Respiration (auto- and heterotrophic)
    - *Long term*: Disturbances (e.g., fire)
6. Plants allocate the products of photosynthesis to maximize capture of the most limiting resource

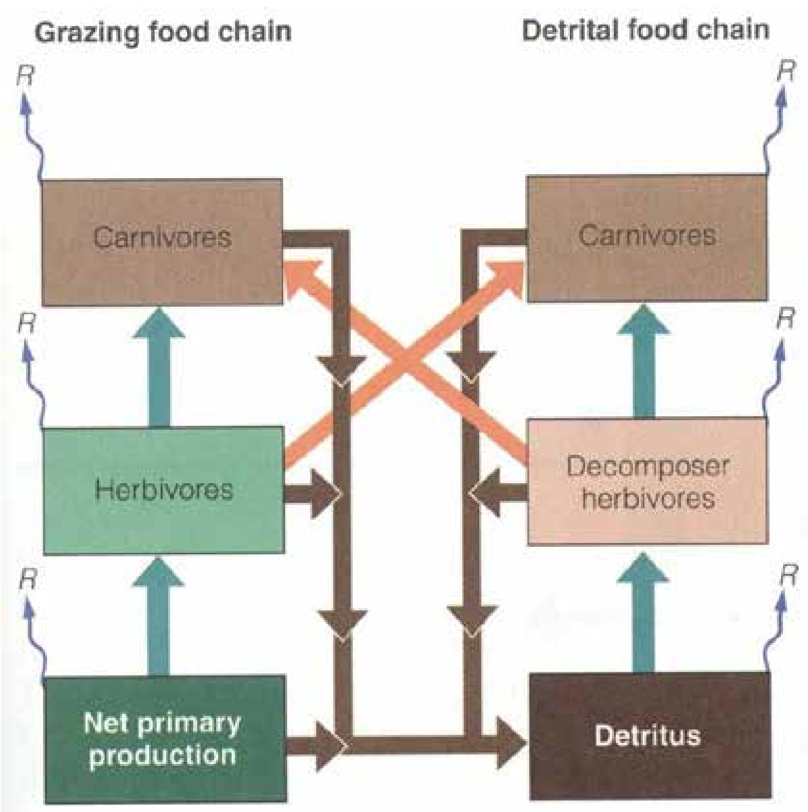
Forest Production Ecology

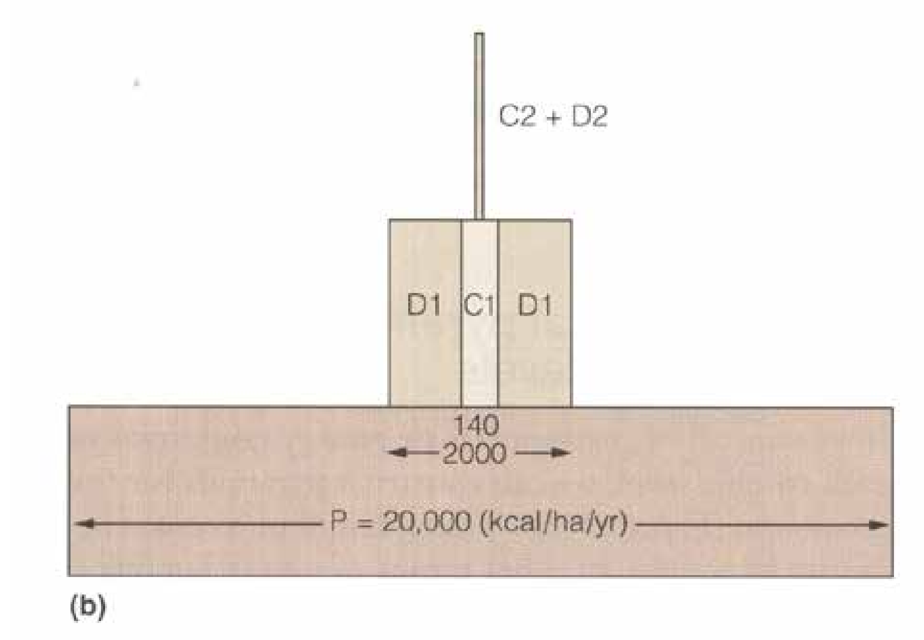
- Trophic Structure and Dynamics
  - Autotrophs (Producers)
    - Photoautotrophs
    - Chemoautotrophs
  - Heterotrophs (Consumers and Decomposers)
    - Herbivores
    - Carnivores
    - Omnivores
    - Saprotrophs

$$\mathbf{6CO_2 + 6H_2O + energy <--> C_6H_{12}O_6 + 6O_2}$$

Forest Production Ecology

- Trophic Structure and Dynamics





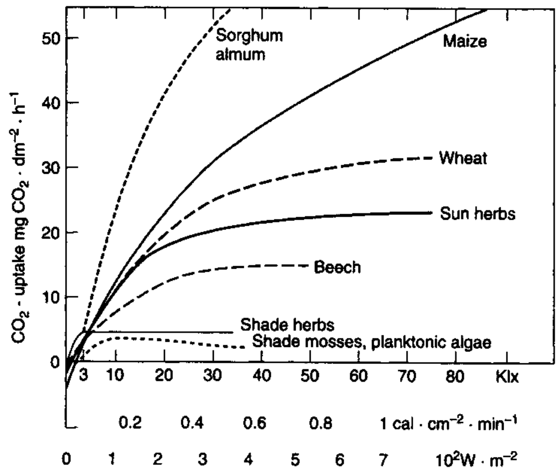
Forest Production Ecology

- Tree Carbon Balance
  - Gross photosynthesis
    - Total C input via photosynthesis
  - Net Photosynthesis
    - Gross Photo. – Foliar Dark Resp. = Net Photo.
      - Energy for driving all metabolic processes
      - Construct new biomass
      - Maintain existing biomass
        - » Defense compounds
        - » VOCs
        - » Storage reserves

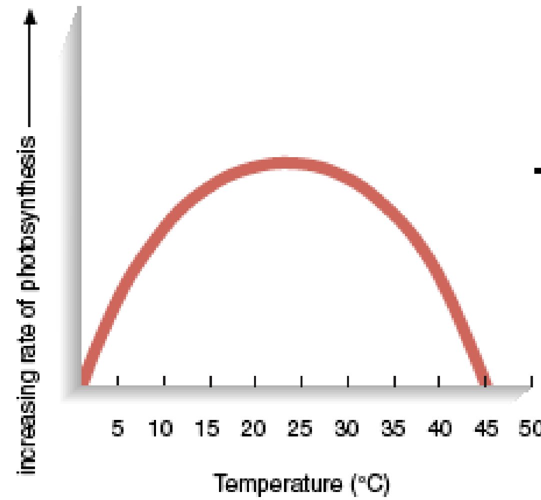
Forest Production Ecology

- Tree Carbon Balance - Net Photosynthesis

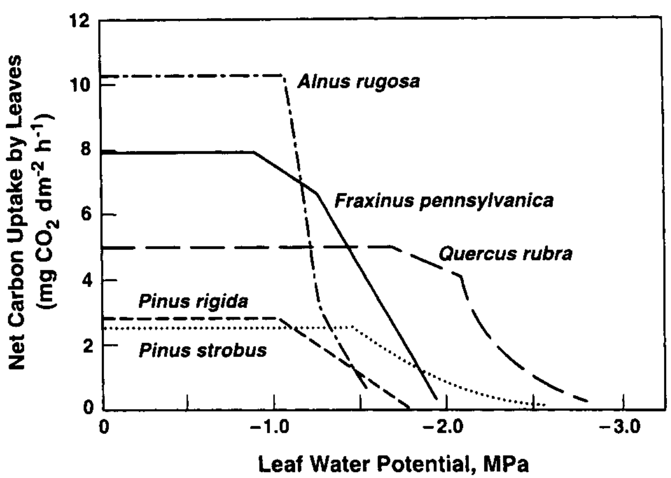
Light



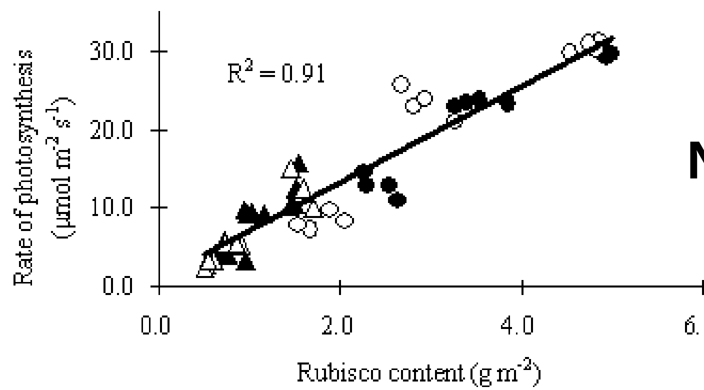
Temperature



H_2O

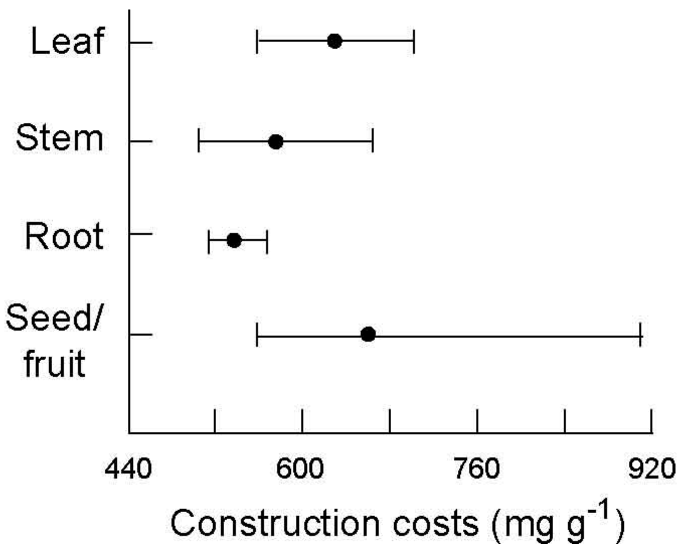


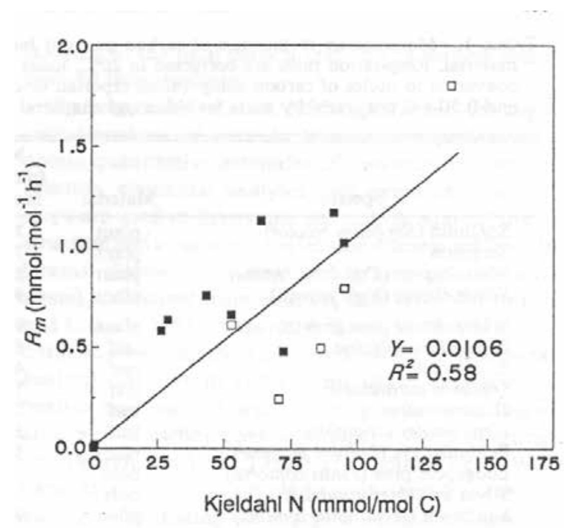
Nutrients

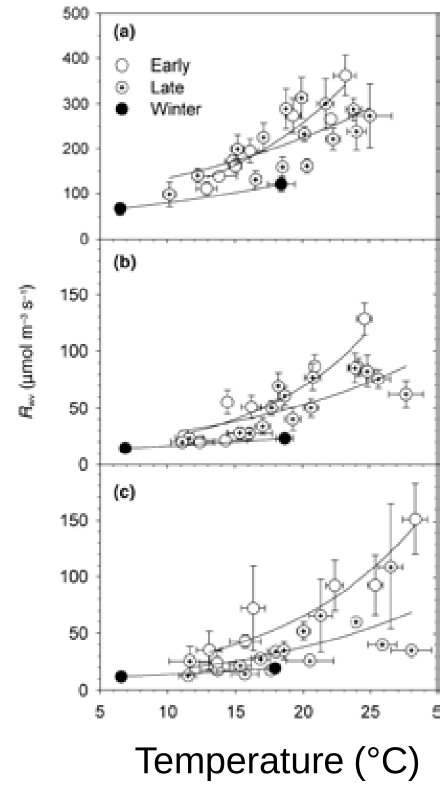


Forest Production Ecology

- Tree Carbon Balance - Respiration







Forest Production Ecology

- Tree Carbon Balance - Allocation

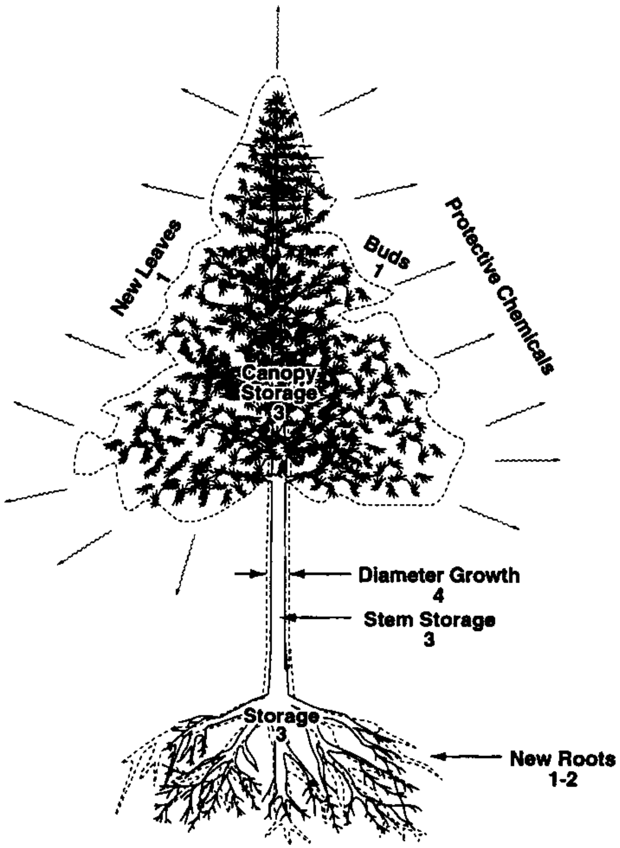


Table 18.3 The carbon budget of a 14-year-old Scots pine tree.

	Assimilation	Allocation	Percent of Total
	g C year^{-1}		
Net Photosynthesis	1723		
Growth			
Current Needles		286	16.6
Branch Axes		132	7.7
Stem		145	8.4
Roots		960	55.6
Total Growth		1523	88.4
Construction and Maintenance Respiration			
Stem		49	2.8
Branch Axes		15	0.9
Roots		109	6.3
Total Respiration		173	10.0
Growth + Respiration		1696	98.5
Unaccounted Net Photosynthesis		27	1.5
TOTAL		1723	100.0

Source: After Agren et al., 1980.

Forest Production Ecology

- Forest Carbon Balance - Biomass

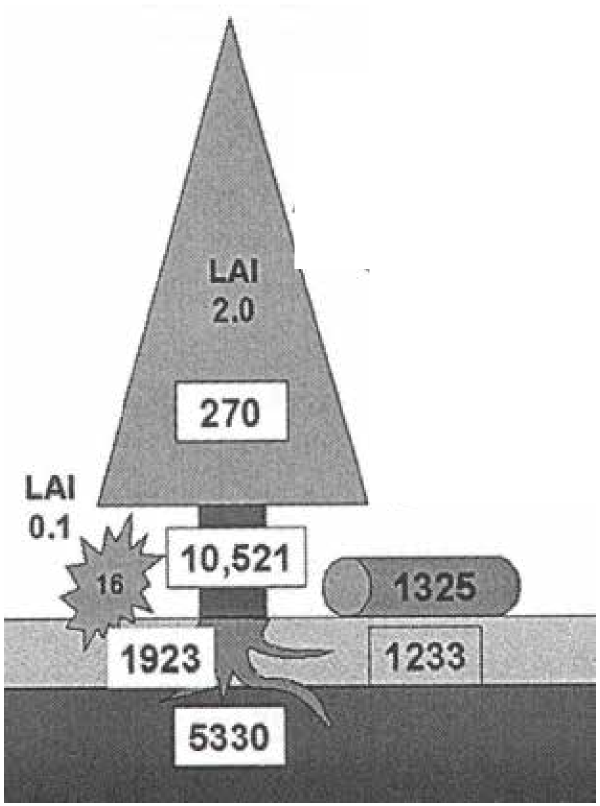
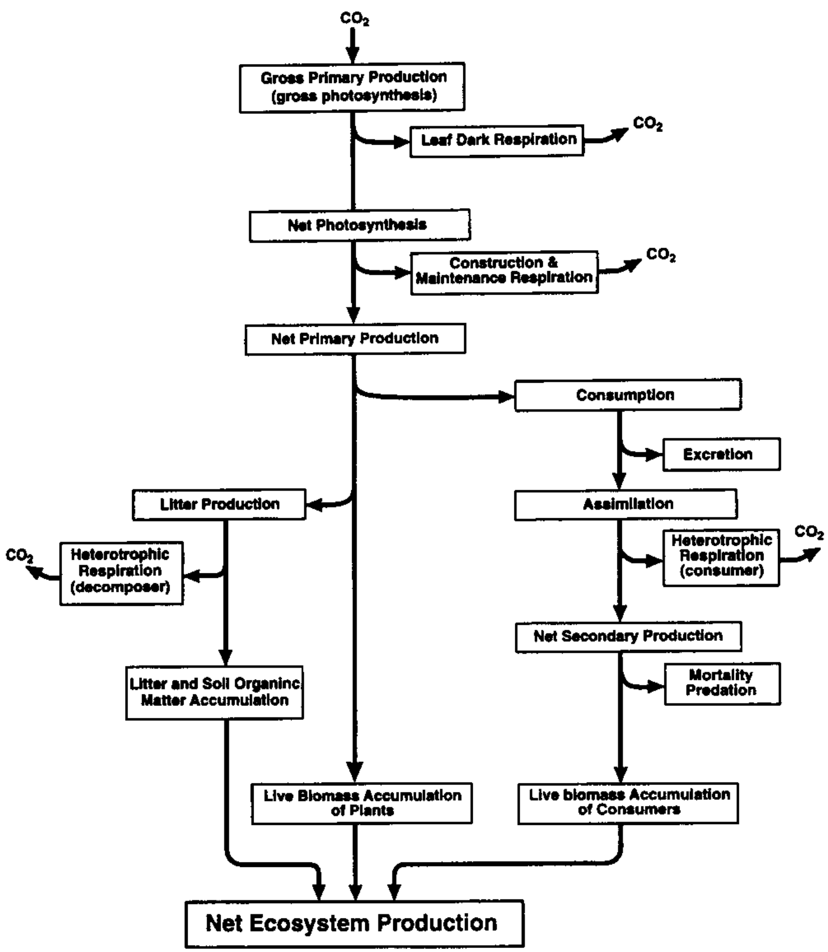


Table 18.5 The distribution of biomass in selected boreal, temperate, and tropical forest ecosystems.

	Boreal	Temperate		Wet Tropical
Location	Alaska USA	Washington USA	New Hampshire USA	Amazon Brazil
Overstory				
Dominant Species	black spruce	Douglas-fir	sugar maple –beech	mixed species[1]
Age (yrs)	95	60	55	mature
Biomass Pools		Mg ha^{-1}		
Overstory	50	410	165	990
Woody Debris	—	9	29	18
Forest Floor	76	15	48	7
Mineral Soil	152	119	173	250
Heterotroph	<1	<1	<4	<1
Total	278	553	419	1265

Forest Production Ecology

- Forest Carbon Balance - Energy Flow



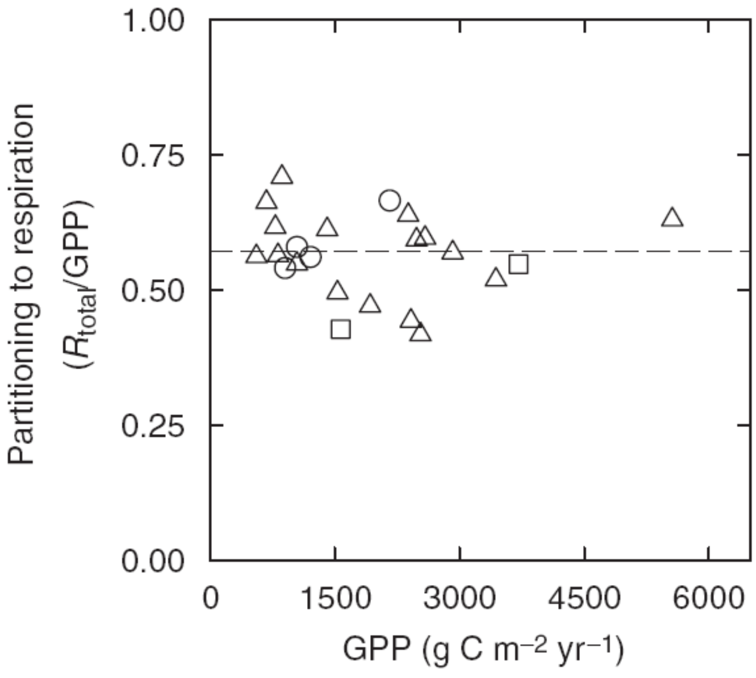
GPP = SPhotosynthesis

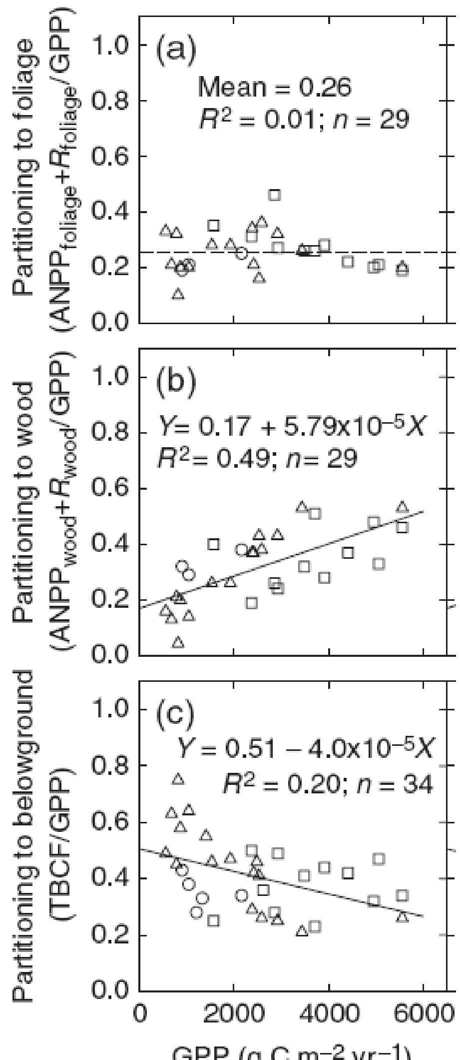
NPP = GPP – R_A

NEP = GPP – (R_A + R_H)

Forest Production Ecology

- Forest Carbon Balance - Allocation

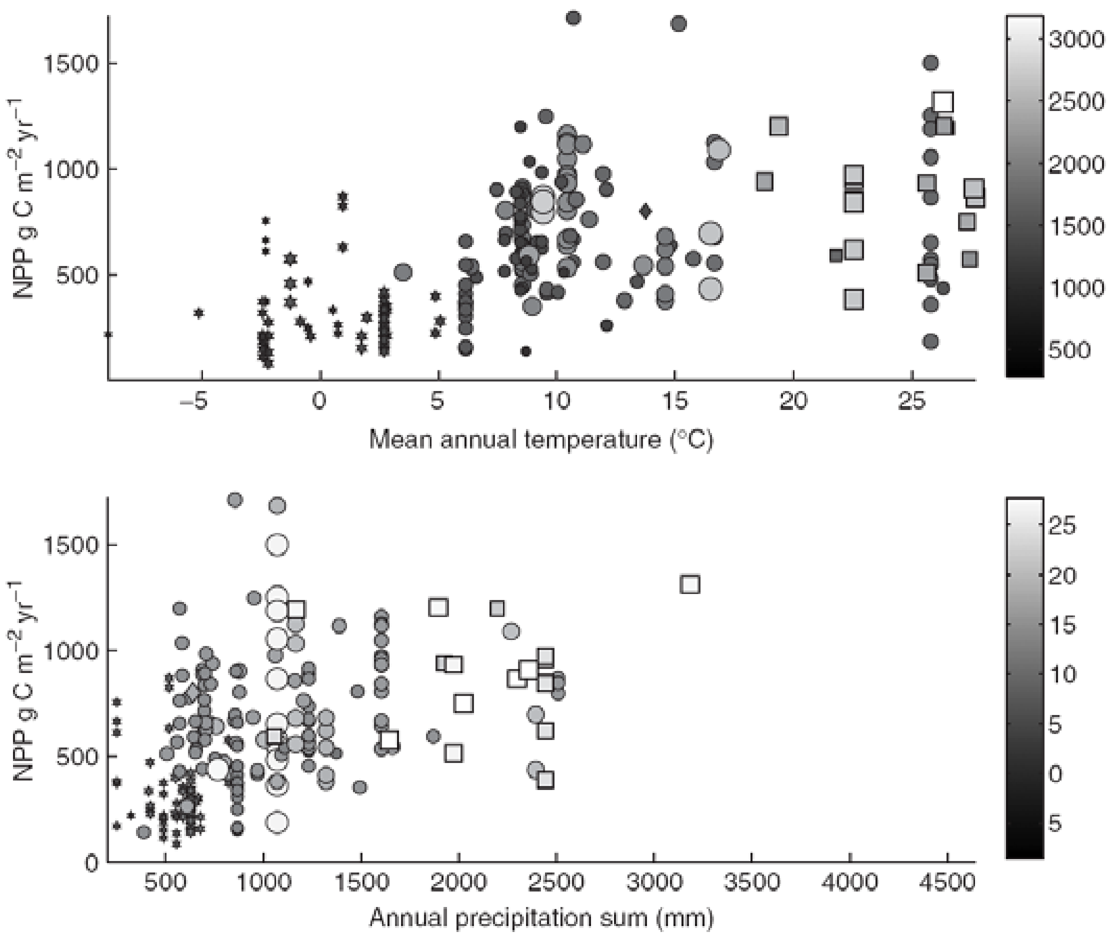




(Litton et al. 2007)

Forest Production Ecology

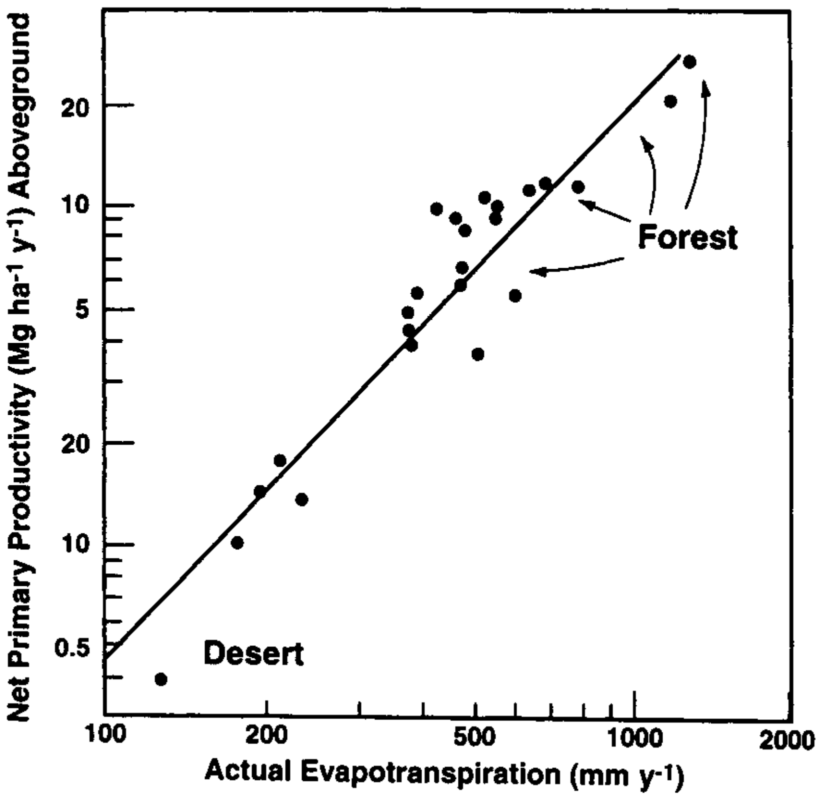
- Forest Carbon Balance - Climate

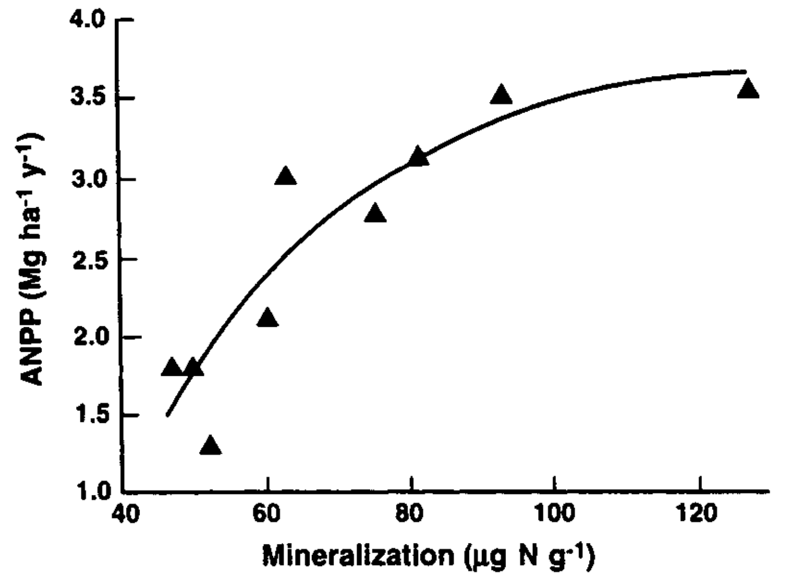


(Luyssaert et al. 2007)

Forest Production Ecology

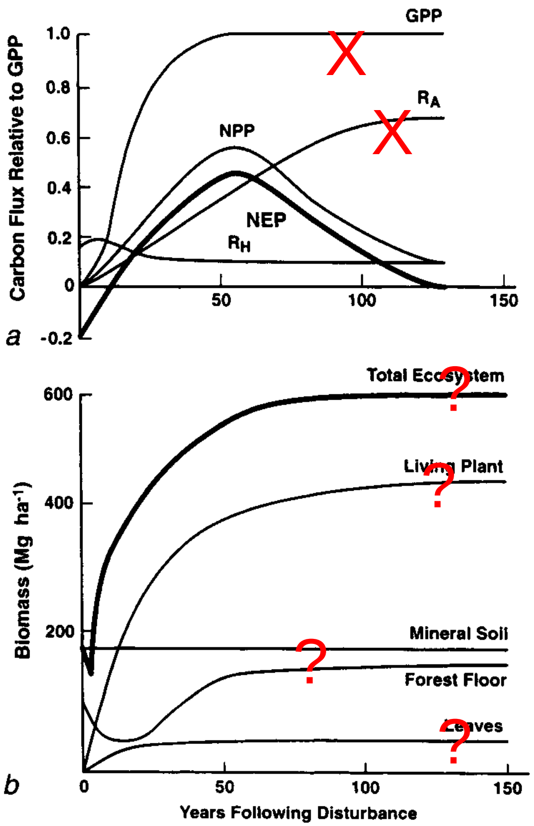
- Forest Carbon Balance - Climate

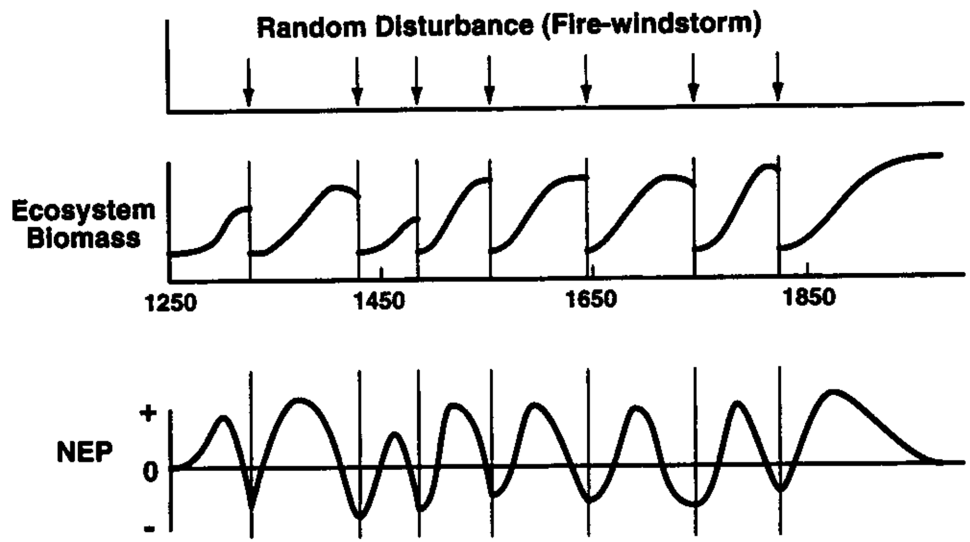




Forest Production Ecology

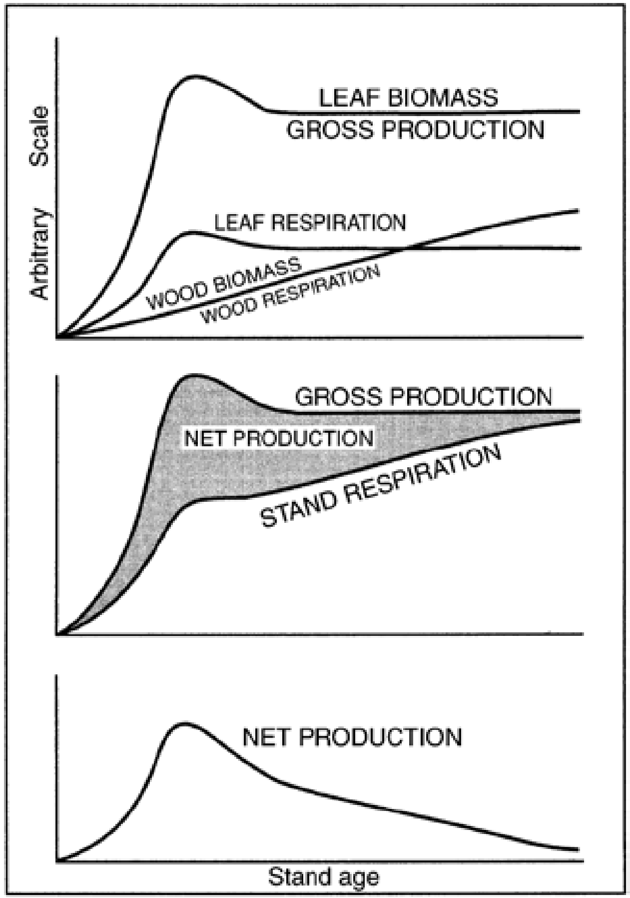
- Forest Carbon Balance - Ecosystem Development





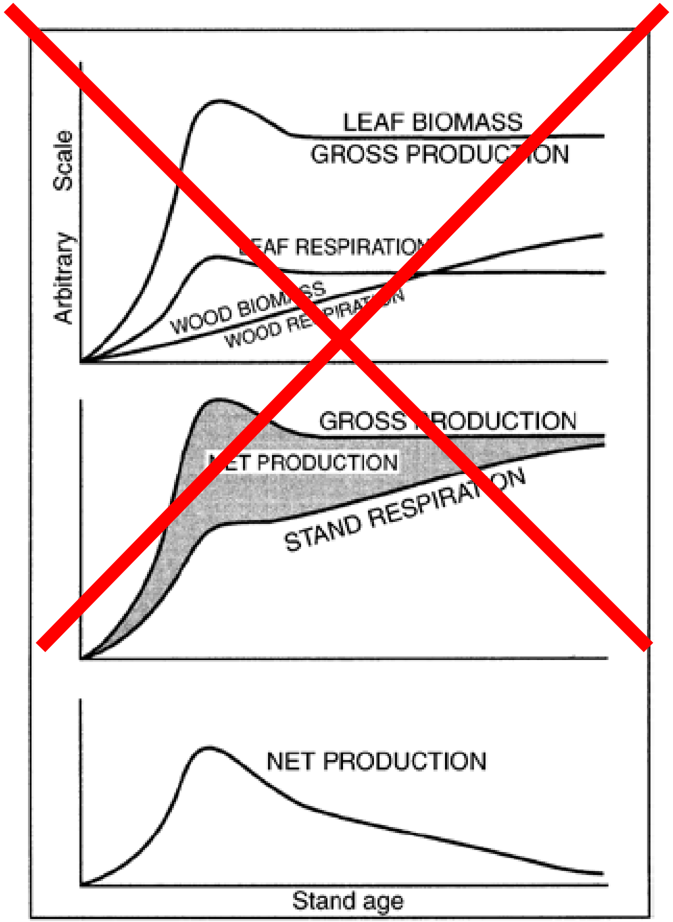
Forest Production Ecology

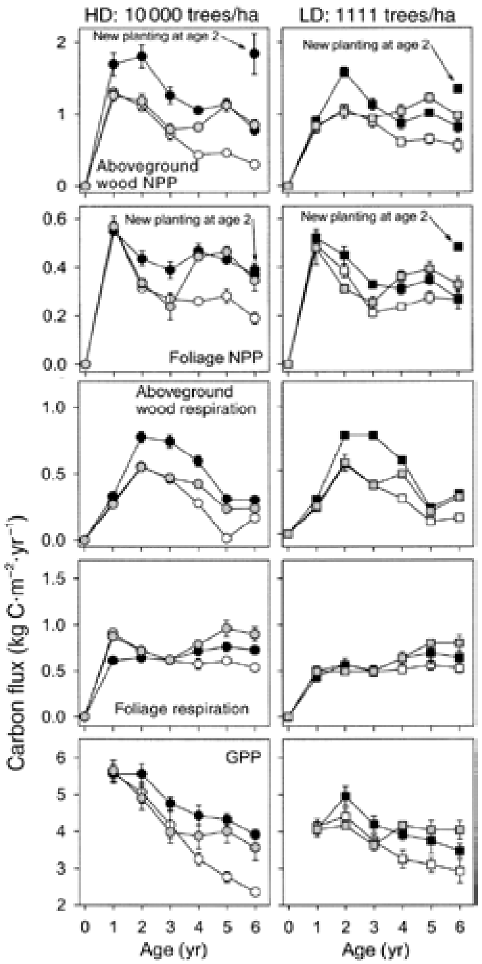
- Age-related decline in forest productivity



Forest Production Ecology

- Age-related decline in forest productivity

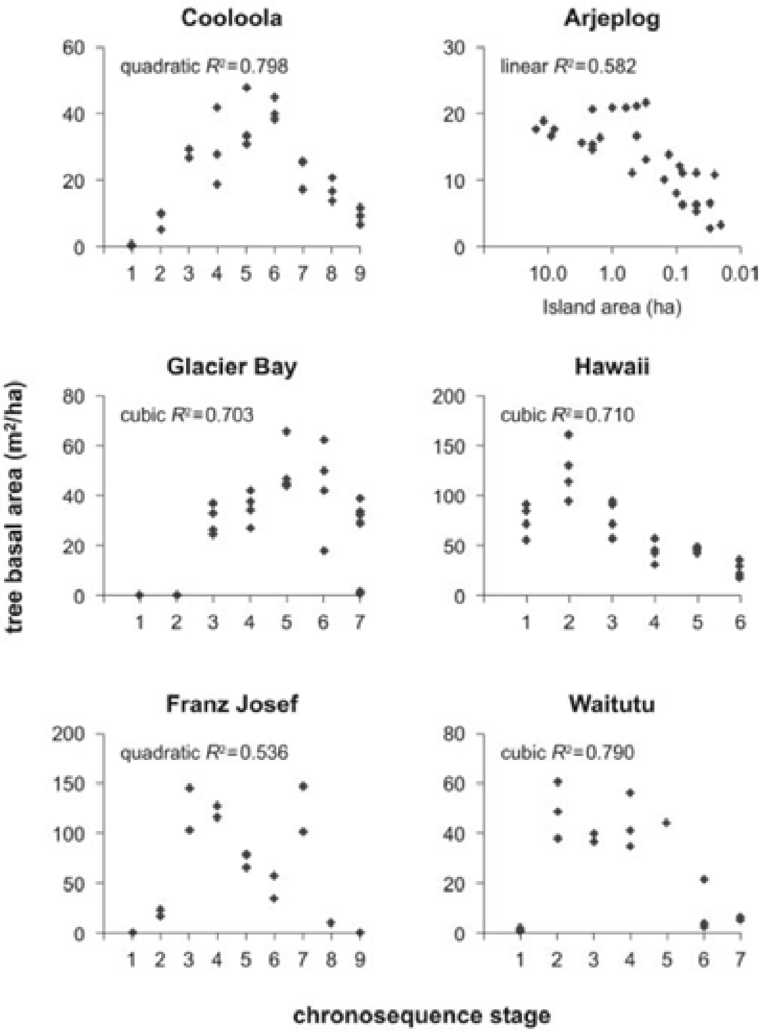




(Ryan et al. 2004)

Forest Production Ecology

- Ecosystem Retrogression



(Wardle et al. 2004)

Forest Production Ecology

- Forest Management
  - Production forestry = manipulating energy (i.e., C)
  - Maximize NPP (by maximizing GPP)
    - GPP is controlled primarily by leaf area (LAI) & growing season length
      - LAI is primarily controlled by access to belowground resources
      - Importance of good soil conservation practices
  - Management can manipulate C allocation (stems)
  - Bioenergy
    - Utilization of the stored energy in biomass

To understand ecosystems we have to understand the ecology of organic matter production and storage… (Kimmins 2004)