Chapter 19

Nutrient Cycling and Retention

Molles: Ecology 3rd Ed.

Chapter Focus

- Nutrient cycling
  - ✓Phosphorus
  - ✓Nitrogen
  - ✓Carbon
  - ✓Water, Sulfur
- Decomposition
- Biotic effect on nutrient distribution and cycling
- Disturbance

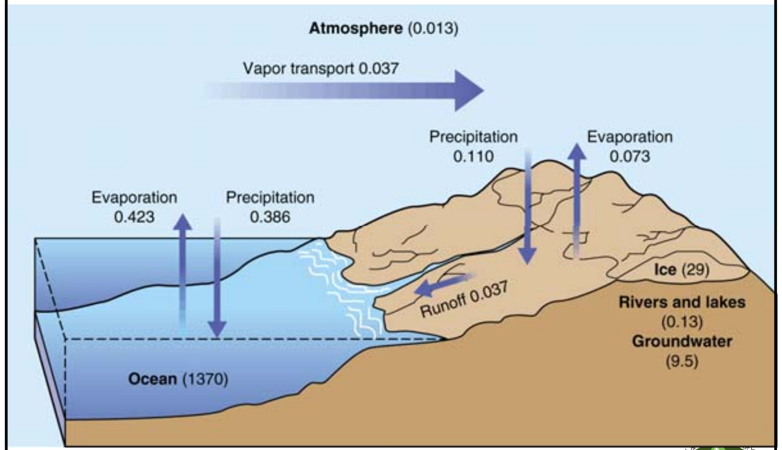
Molles: Ecology 3rd Ed.

Global biogeochemical cycles

- Nutrients are moved by winds & water (groundwater, streams, currents)
- No boundaries
- Global in scale

Molles: Ecology 3rd Ed.

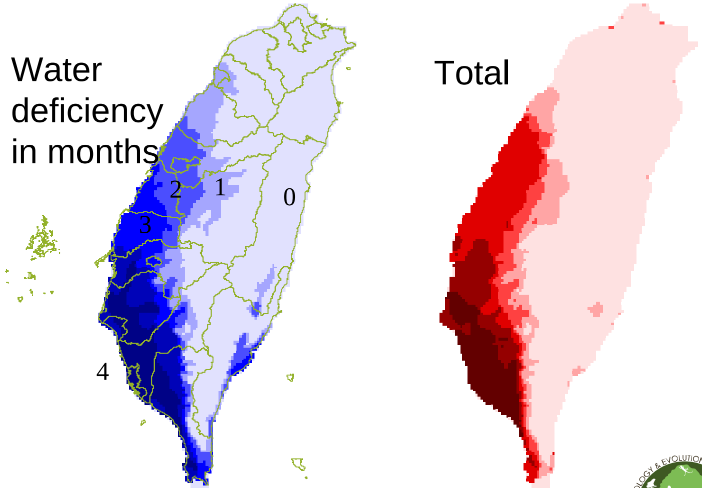
The hydrological cycle



Molles: Ecology 3rd Ed.

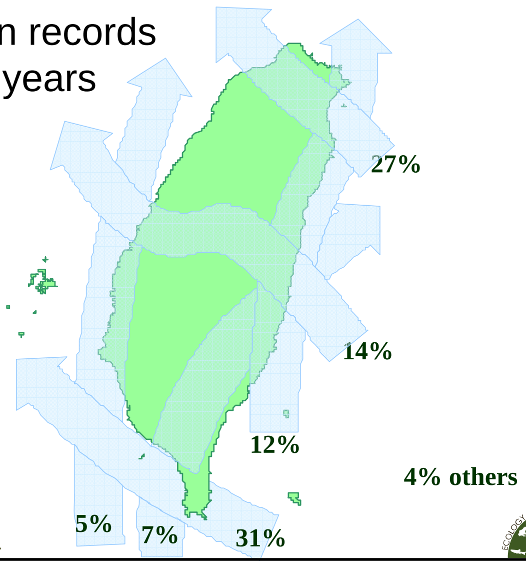
Lake Hovsgol (136 Km * 36 Km), Mongolia
1% of world's freshwater

Taiwan's situation

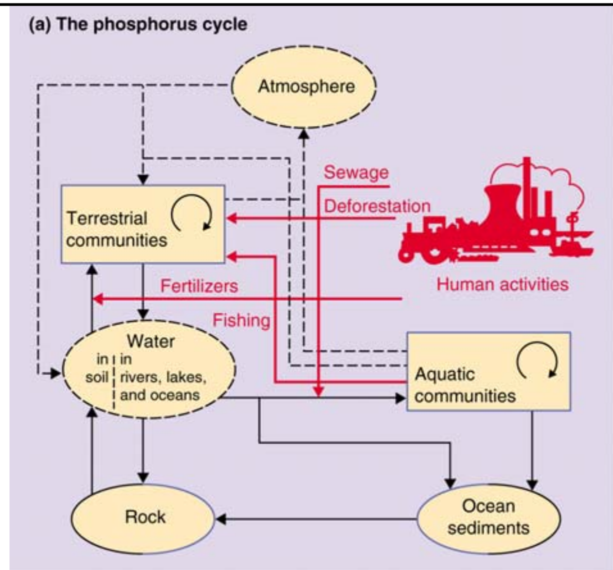


Molles: Ecology 3rd Ed.

Typhoon records
100 years



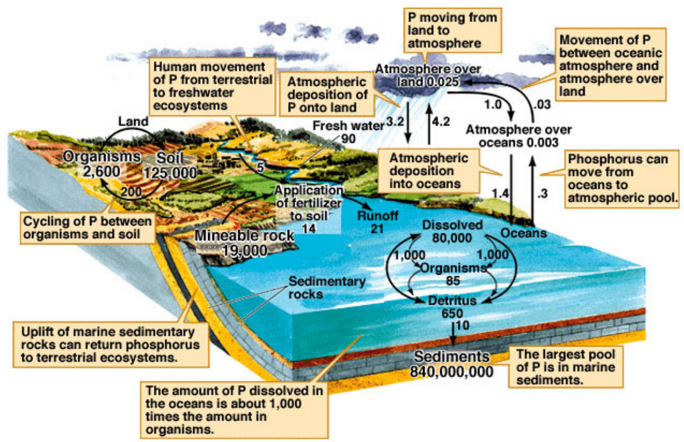
Molles: Ecology 3rd Ed.

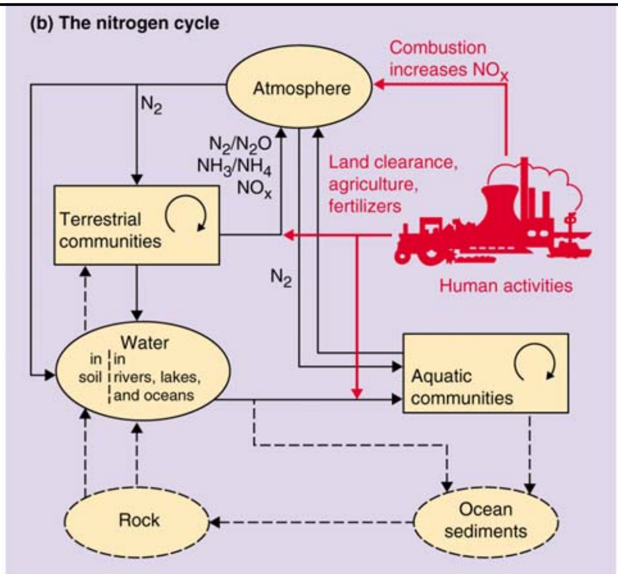


Phosphorus Cycle

- Global phosphorus cycle does not include substantial atmospheric pool
  - ✓ Largest quantities found in mineral deposits and marine sediments
    - Much of this in forms not directly available to plants
  - ✓ Slowly released in terrestrial and aquatic ecosystems via weathering of rocks

The Phosphorus Cycle

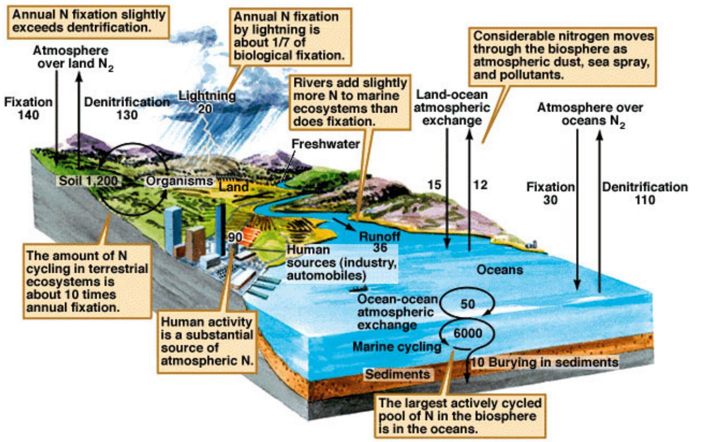




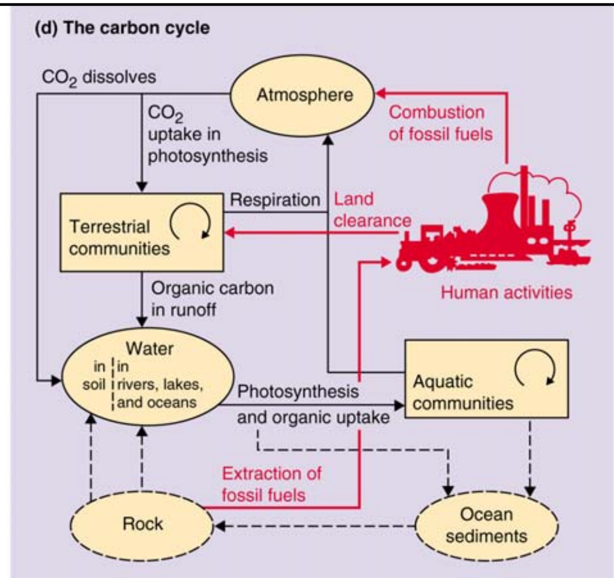
Nitrogen Cycle

- Includes major atmospheric pool – N_2
  - ✓ Only nitrogen fixers can use atmospheric supply directly
    - Energy-demanding process
      - N_2 reduced to ammonia (NH_3)
    - Once N is fixed – available to organisms
      - Upon death of organism, N can be released by fungi and bacteria during decomposition

The Nitrogen Cycle



Molles: Ecology 3rd Ed.

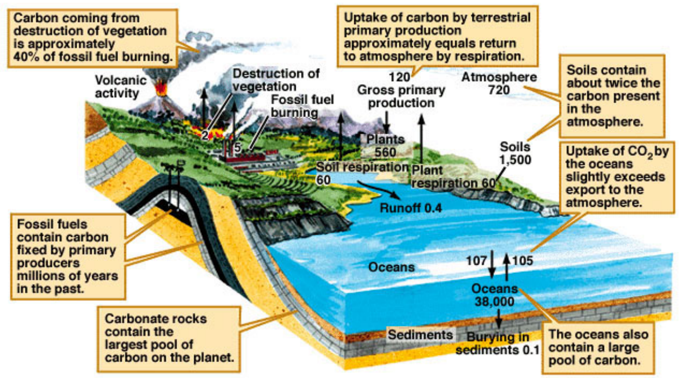


Carbon Cycle

- Moves between organisms and atmosphere as a consequence of photosynthesis and respiration
  - ✓In aquatic ecosystems, CO_2 must first dissolve into water before being used by primary producers
  - ✓Although some C cycles rapidly, some remains sequestered in unavailable forms for long periods of time

Molles: Ecology 3rd Ed.

The Carbon Cycle



Molles: Ecology 3rd Ed.

Human impacts on biogeochemical cycles

- Human activities contribute significant inputs of nutrient to ecosystem and disrupt local and global biogeochemical cycles
- Fox example: burning of fossil fuels (CO_2, NO & S), agricultural practices and sewage disposal (N & P)
- *Discussed later*

Concepts

- Decomposition rate is influenced by temperature, moisture, and chemical composition of litter and environment
- Plants and animals can modify the distribution and cycling of nutrients in ecosystems
- Disturbance increases ecosystem nutrient loss

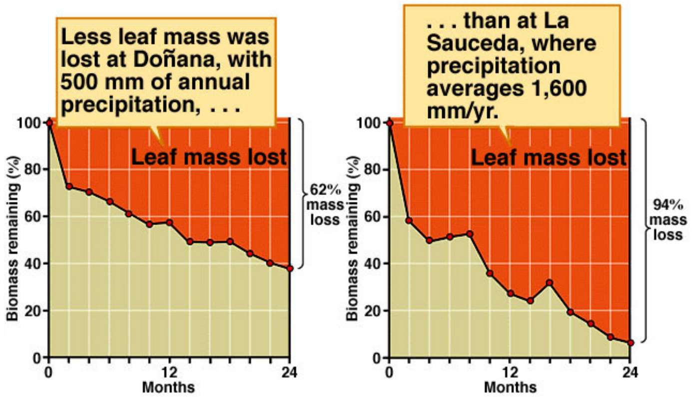
Decomposition Rates

- Rate at which nutrients are made available to primary producers is determined largely by rate of mineralization
  - ✓ Occurs primarily during decomposition
    - Rate in terrestrial systems is significantly influenced by temperature, moisture, and chemical compositions

Decomposition – Mediterranean

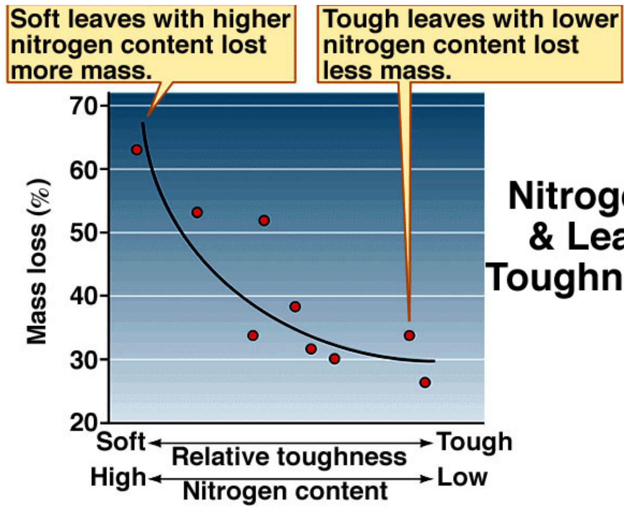
- Gallardo and Merino found chemical and physical factors affected rates of decomposition in woodland ecosystems
- Study sites: same temperature, but different elevation and precipitation
- Different decomposition rates due to precipitation, leaf toughness, and N contents

Leaf Decomposition



Molles: Ecology 3rd Ed.

Nitrogen & Leaf Toughness



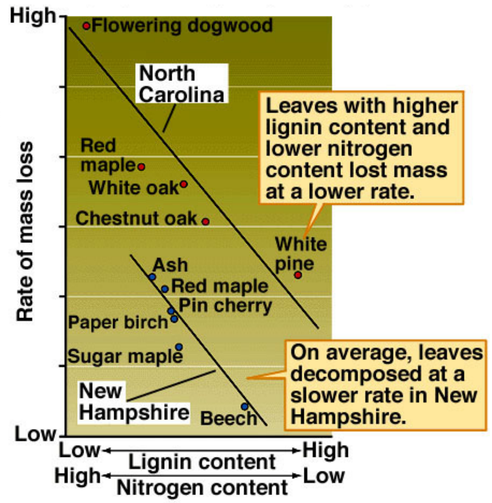
Molles: Ecology 3rd Ed.

Decomposition in Temperate Forest Ecosystems

- *Melillo et al*. used litter bags to study decomposition in temperate forests
  - ✓Found leaves with higher lignin:nitrogen ratios lost less mass
    - Suggested higher N availability in soil might have contributed to higher decomposition rates
    - Higher environmental temperatures may have also played role

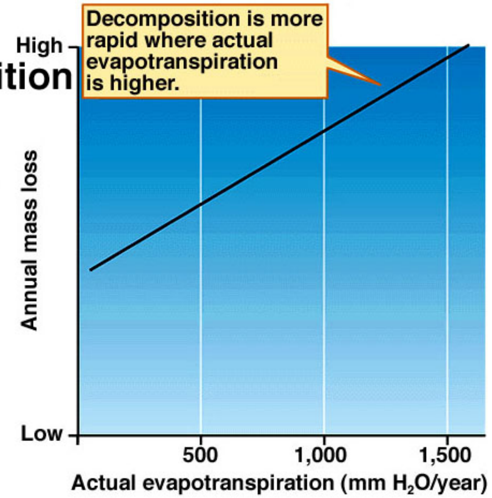
Molles: Ecology 3rd Ed.

Lignin & Nitrogen in Leaves

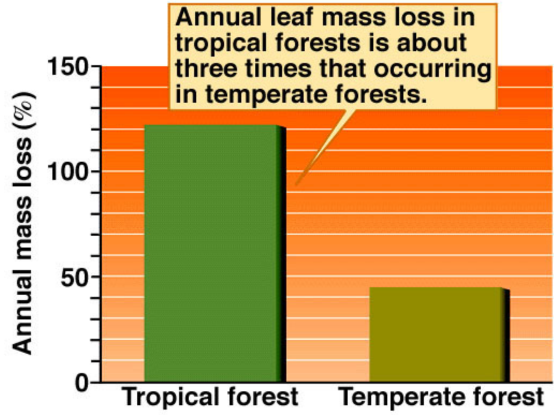


Molles: Ecology 3rd Ed.

AET & Decomposition



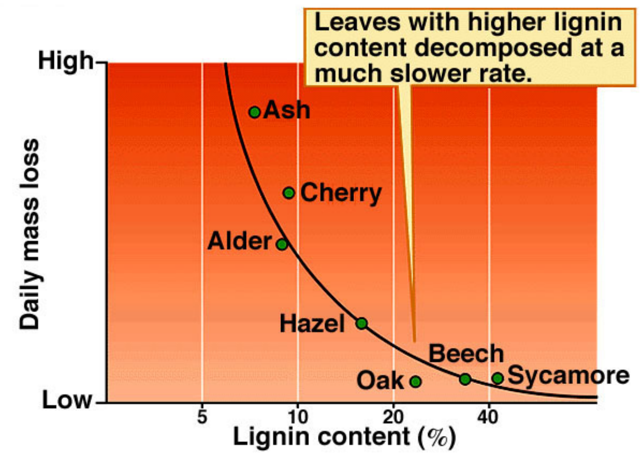
Forest Decomposition



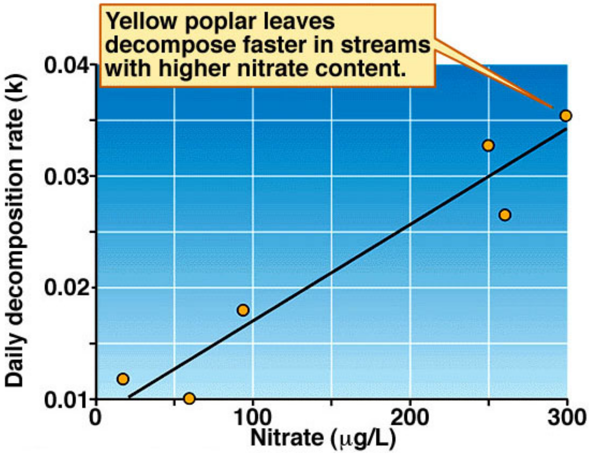
Decomposition in Aquatic Ecosystems

- *Gessner and Chauvet* found leaves with a higher lignin content decomposed at a slower rate
  - ✓ Higher lignin inhibits fungi colonization of leaves
- *Suberkropp and Chauvet* found leaves degraded faster in streams with higher nitrate concentrations

Leaf Lignin & Decomposition

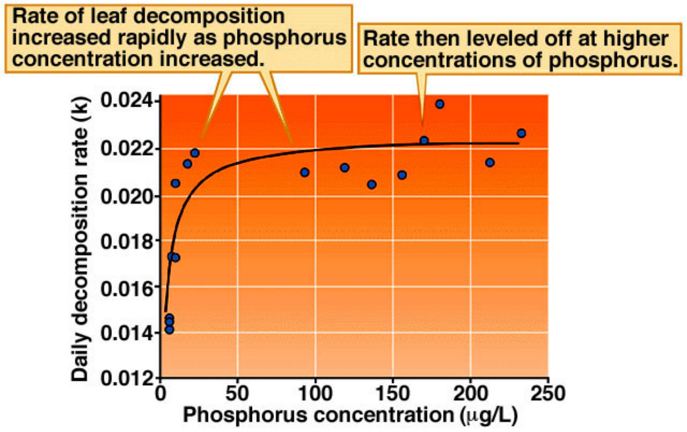


Nitrate & Decomposition



Molles: Ecology 3rd Ed.

Phosphorus & Decomposition



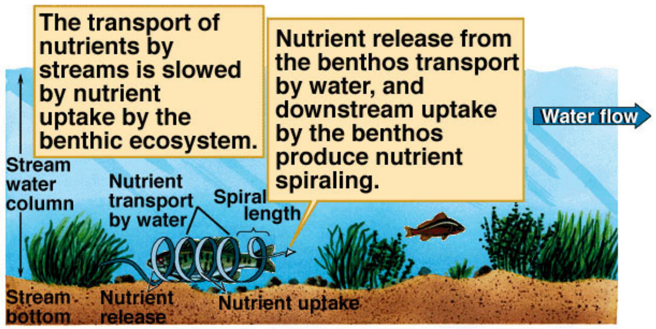
Molles: Ecology 3rd Ed.

Nutrient Cycling in Streams

- *Webster* pointed out nutrients in streams are subject to downstream transport
  - ✓Little nutrient cycling in one place
    - Nutrient Spiraling
  - ✓Spiraling Length = Length of stream required for a nutrient atom to complete a cycle
    - Related to rate of nutrient cycling and velocity of downstream nutrient movement

Molles: Ecology 3rd Ed.

Nutrient Spiraling in Streams



Molles: Ecology 3rd Ed.

Nutrient Cycling in Streams

- Spiraling Length (S):

$$S = VT$$

V = Average velocity of a nutrient atom

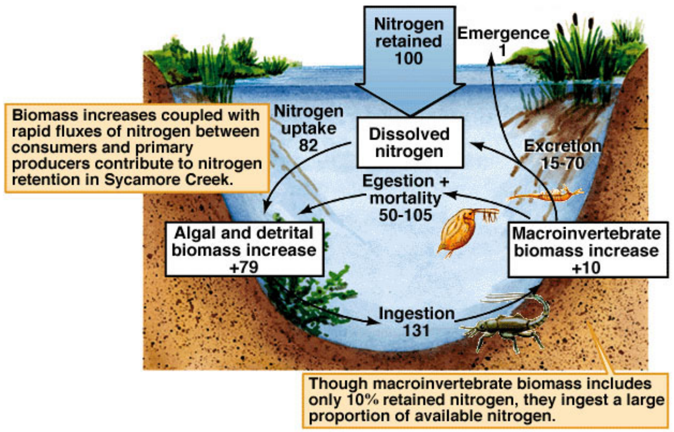
T = Average time to complete a cycle

  - ✓Short lengths = high nutrient retentiveness
  - ✓Long lengths = low nutrient retentiveness

Stream Invertebrates and Spiraling Length

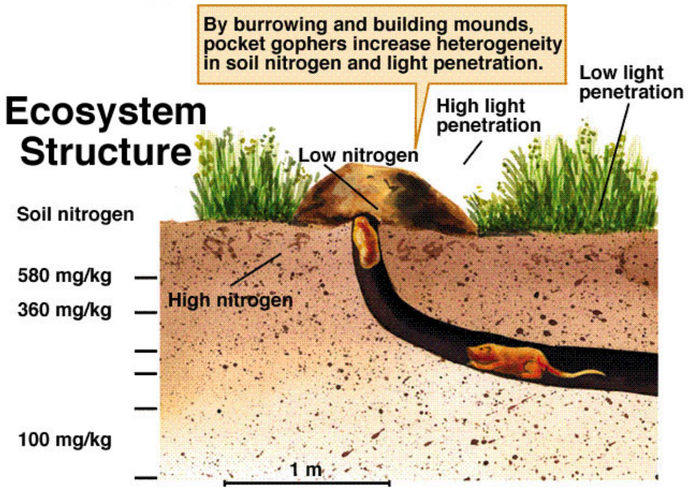
- *Grimm* showed aquatic invertebrates significantly increase rate of N cycling
  - ✓Suggested rapid recycling of N by macroinvertebrates may increase primary production
    - Excreted and recycled 15-70% of nitrogen pool as ammonia

Nitrogen Fluxes



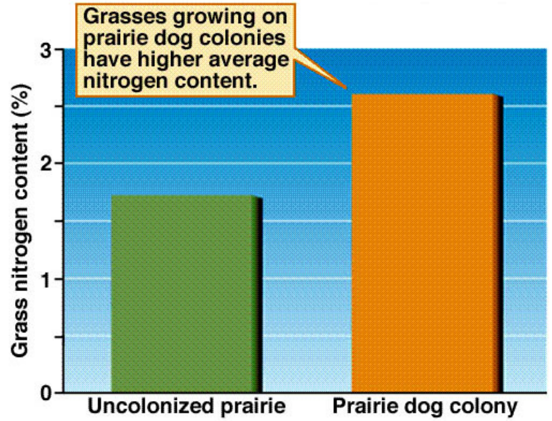
Animals and Nutrient Cycling in Terrestrial Ecosystems

- *Huntley and Inouye* found pocket gophers altered N cycle by bringing N-poor subsoil to the surface
- *Whicker and Delting* found prairie dog's feeding activity affected nutrient distribution in grassland ecosystem



Molles: Ecology 3rd Ed.

Nitrogen & Grass Location

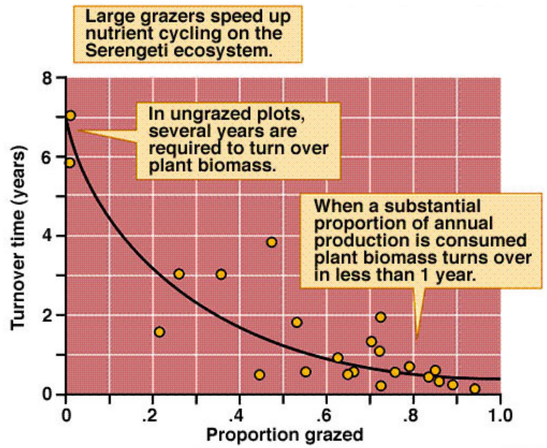


Molles: Ecology 3rd Ed.

- *MacNaughton* found a positive relationship between grazing intensity and rate of turnover in plant biomass in Serengeti Plain
  - ✓Without grazing, nutrient cycling occurs more slowly through decomposition and feeding of small herbivores

Molles: Ecology 3rd Ed.

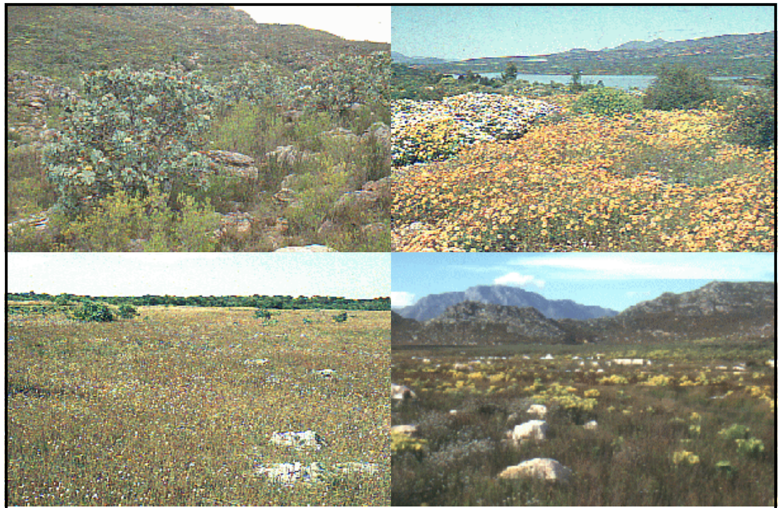
Biomass Turnover & Grazing



Molles: Ecology 3rd Ed.

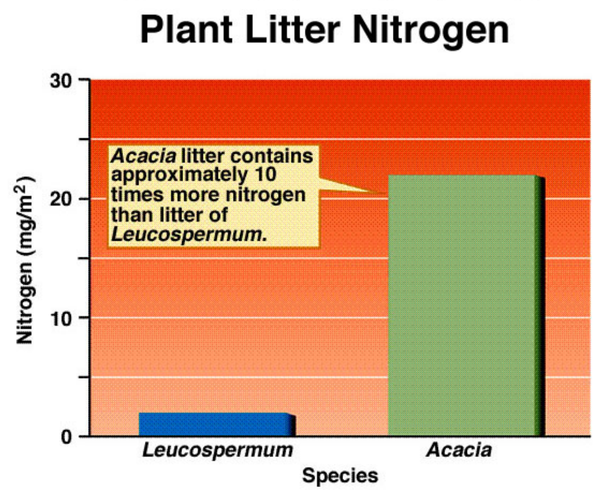
Plants and Ecosystem Nutrient Dynamics

- Fynbos is a temperate shrub/woodland known for high plant diversity and low soil fertility
  - ✓Two species of *Acacia* used to stabilize shifting sand dunes
  - ✓Altering nutrient dynamic
    - Decomposition rate
    - Litter
    - Soil N



http://www.botany.uwc.ac.za/envfacts/fynbos/fynbos.htm

- *Witkowski* compared nutrient dynamics under canopy of native shrub and introduced *Acacia*
  - ✓Amount of litter was similar, but nutrient content was significantly different
  - ✓*Acacia* – N fixer



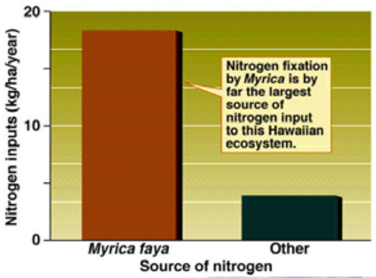
銀合歡*Leucaena*

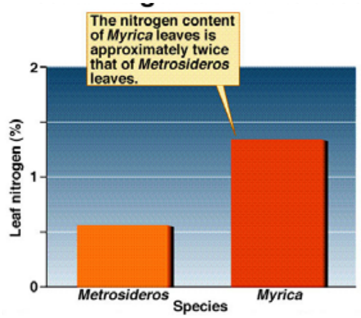
Introduced Tree and Hawaiian Ecosystem

- *Vitousek and Walker* found invading N-fixing tree *Myrica faya* is altering N dynamics of Hawaiian ecosystems
  - ✓Introduced in late 1800's as ornamental or medicinal plant – later used for watershed reclamation
    - Nitrogen fixation by *Myrica* large N input
      - Leaves contain high N content
        - High decomposition rate

Molles: Ecology 3rd Ed.

Introduced Tree & Nitrogen





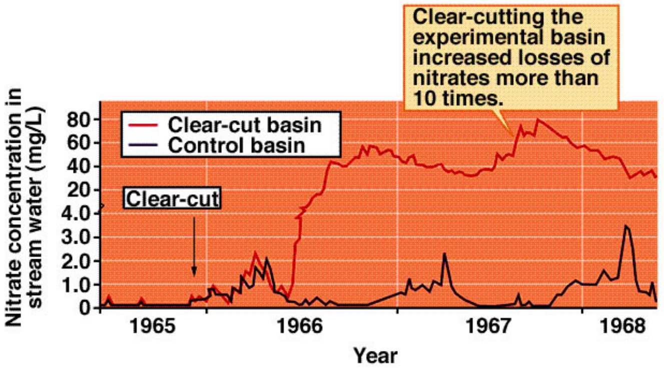
Molles: Ecology 3rd Ed.

Disturbance and Nutrient Loss - the Hubbard Brook Forest

- *Vitousek* studied effects of disturbance and environmental conditions on N loss
  - ✓Trenching increased concentrations of nitrate in soil water up to 1,000 x
    - Nitrate losses generally greatest at sites with rapid decomposition
      - Uptake by vegetation is most important in ecosystems with fertile soils and warm, moist conditions

Molles: Ecology 3rd Ed.

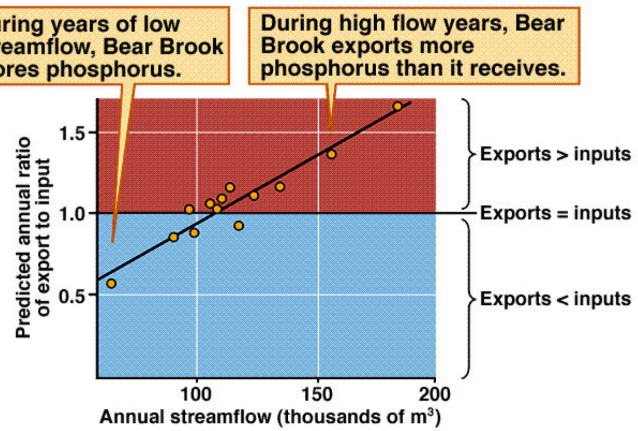
Deforestation & Nitrate Loss



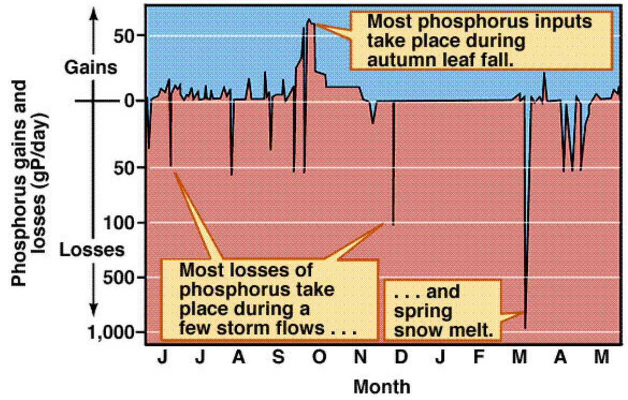
Flooding and Nutrient Export by Streams

- *Meyer and Likens* found P exports were highly episodic and associated with periods of high flow
  - ✓ Annual peak in P input associated with spring snowmelt
    - Most export was irregular because it was driven by flooding caused by intense periodic storms

Phosphorus Import to Export



Daily Phosphorus Change



Summary

- Decomposition rate is influenced by temperature, moisture, and chemical composition of litter and environment
- Plants and animals can modify the distribution and cycling of nutrients in ecosystems
- Disturbance increases ecosystem nutrient loss

Molles: Ecology 3rd Ed.