Prof dr. Idham Ali Abed
collage of Agriculture University of Anbar

How much N is added in agriculture?

Cotton 56-78 Kg/ha

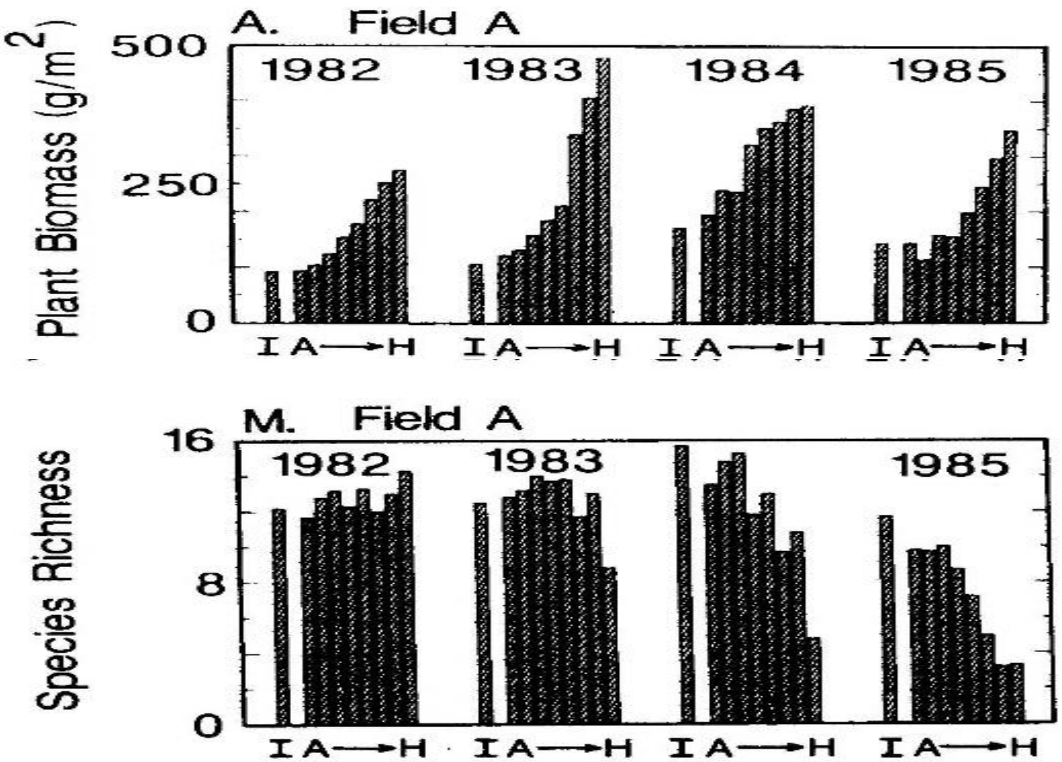
- Iowa corn 170-225 Kg/ha
- Taiwan rice: 270 Kg/ha

Consequences

- Eutrophication
- Species changes/losses
- *Atmospherically active trace gases*

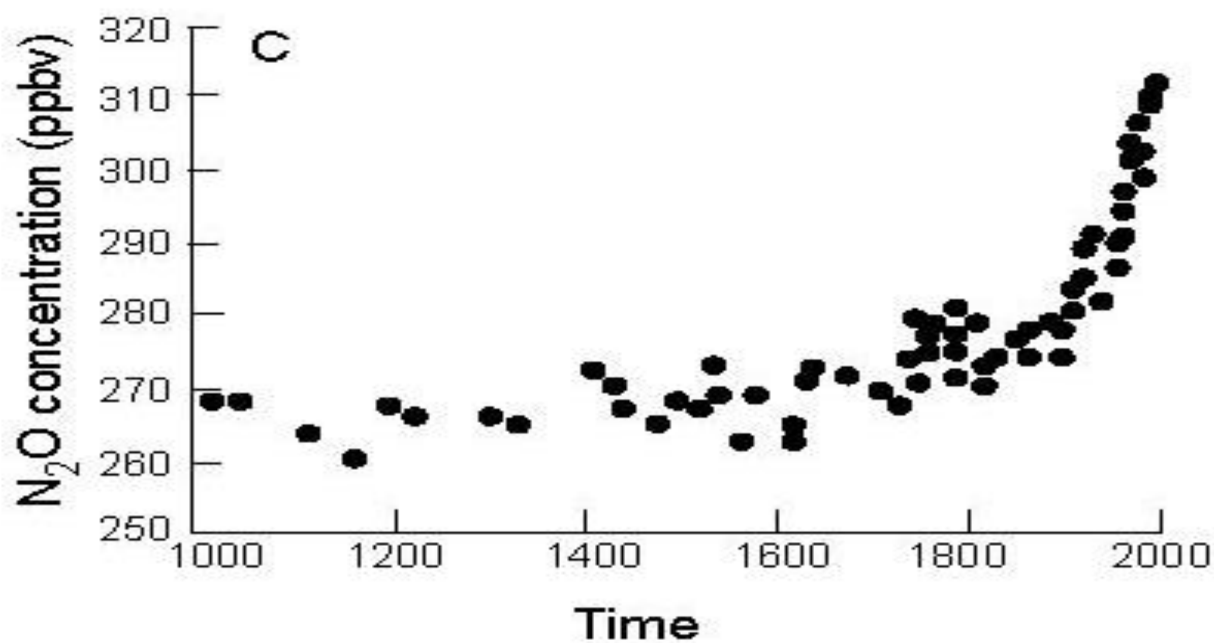
N fert → increasing prod.

N fert → increasing dominance, decreasing diversity



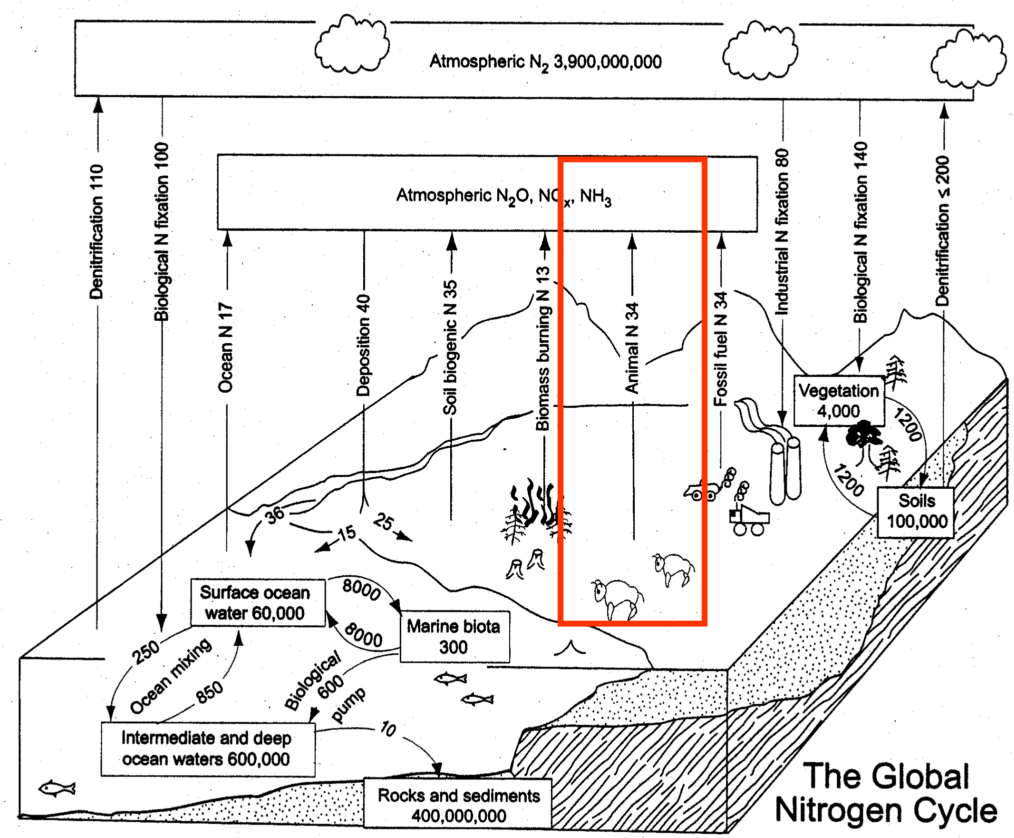
Tilman 1987

- Eutrophication Species changes/losses
- Atmospherically active trace gases
  - $NO + NO_2$ (NO_x): fossil fuel combustion
    - NO (highly reactive) → smog, tropospheric O_3 formation
    - Acid rain ($NO_2 + OH^- \rightarrow HNO_3$)
  - N_2O: increased fertilizer application → denitrification
    - Potent greenhouse gas (200x more effective than CO_2, 6% of total forcing)
    - Chemically inert in troposphere, but catalyzes destruction of O_3 in stratosphere
  - NH_3



Consequences

- Eutrophication
- Species changes/losses
- Atmospherically active trace gases
  - NH_3: domestic animals, ag fields (fert), biomass burning
    - Atmospherically active → aerosols, air pollution
    - Deposition, N availability downwind



- N deposition → increased growth (C sequestration)…to a point.
- N saturation: availability exceeds demand
  - Associated with decreases in forest productivity, potentially due to indirect effects such as acidification, altered plant cold tolerance
- N saturation → N losses → “opening” of the N cycle

. Controls on N cycle fluxes in soil
A. N Inputs

1. Biological N fixation
2. Atmospheric N deposition
3. Mineral weathering?

1. Biological N Fixation

a. What is it?

- Conversion of atmospheric N_2 to NH_4^+ (actually, amino acids)
- Under natural conditions, nitrogen fixation is the main pathway by which new, available nitrogen enters terrestrial ecosystems

Nitrogen fixation

b. Who does it?

- Carried out by bacteria
  - Symbiotic N fixation (e.g., legumes, alder)
  - Heterotrophic N fixation (rhizosphere and other carbon-rich environments)
  - Phototrophs (bluegreen algae)
- The characteristics of **nitrogenase**, the enzyme that catalyzes the reduction of N_2 to NH_4^+, dictate much of the biology of nitrogen fixation
  - High-energy requirement (N triple bond)
    - Requires abundant energy and P for ATP
  - Inhibited by O_2
  - Requires cofactors (e.g., Mo, Fe, S)

Types of N-fixers

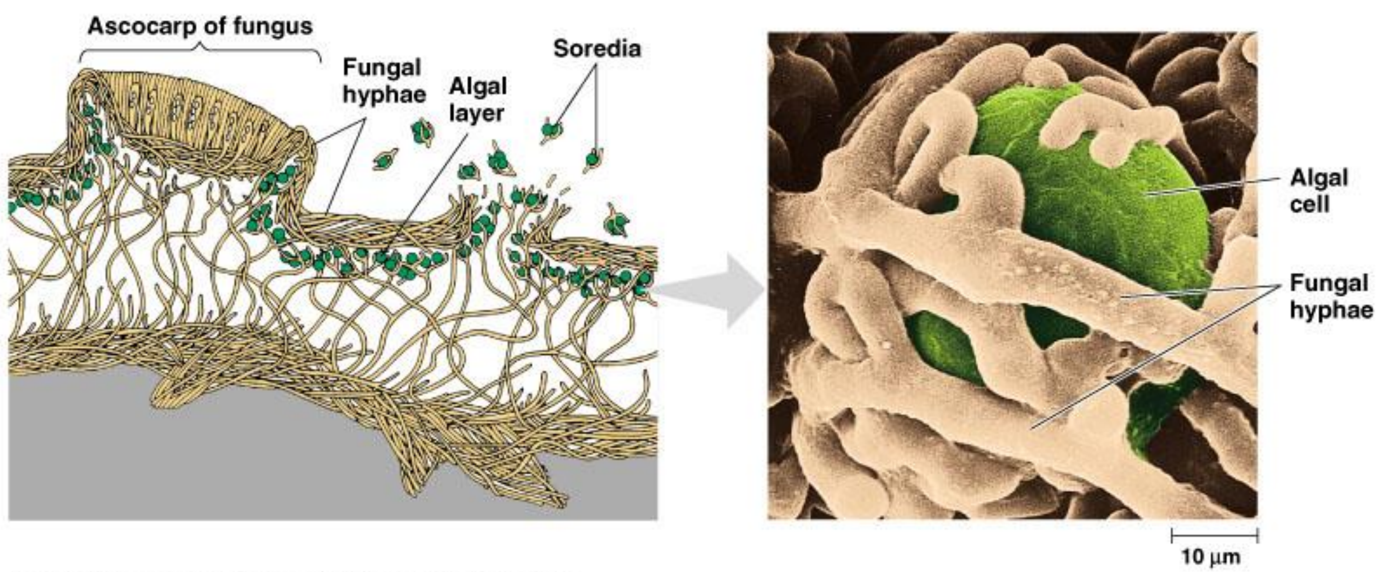
- There's no such thing as a N-fixing plant
- Symbiotic N-fixers
  - High rates of fixation (5-20+ g-N m^{-2} y^{-1}) with plants supplying the C (and the plant receiving N)
  - Protection from O_2 via leghemoglobin (legumes)
  - Microbial symbiont resides in root nodules
    - Bacteria (*Rhizobia*) – Legumes (*Lupinus*, *Robinia*)
    - Actinomycetes (*Frankia*) - *Alnus*, *Ceanothus* (woody non-legumes)
  - N-fixation rates reduced in presence of high N availability in the soil

Types of N fixers

- Associative N fixers
  - Occur in **rhizosphere** of plants (non-nodulated); moderate rates with C supply from plant root turnover and exudates (1-5 g-N m^{-2} y^{-1})
  - Reduced $[O_2]$ by rapid respiration from plant roots
  - *Azotobacter*, *Bacillus*

Types of N fixers

- Free-living N fixers
  - Heterotrophic bacteria that get organic C from environment and where N is limiting (e.g., decaying logs)
  - Rates low due to low C supply and lack of O_2 protection (0.1-0.5 g-N m^{-2} y^{-1})
- Also, **cyanobacteria** (free-living photo-autotrophs); symbiotic **lichens** (cyanobacteria with fungi offering physical protection)

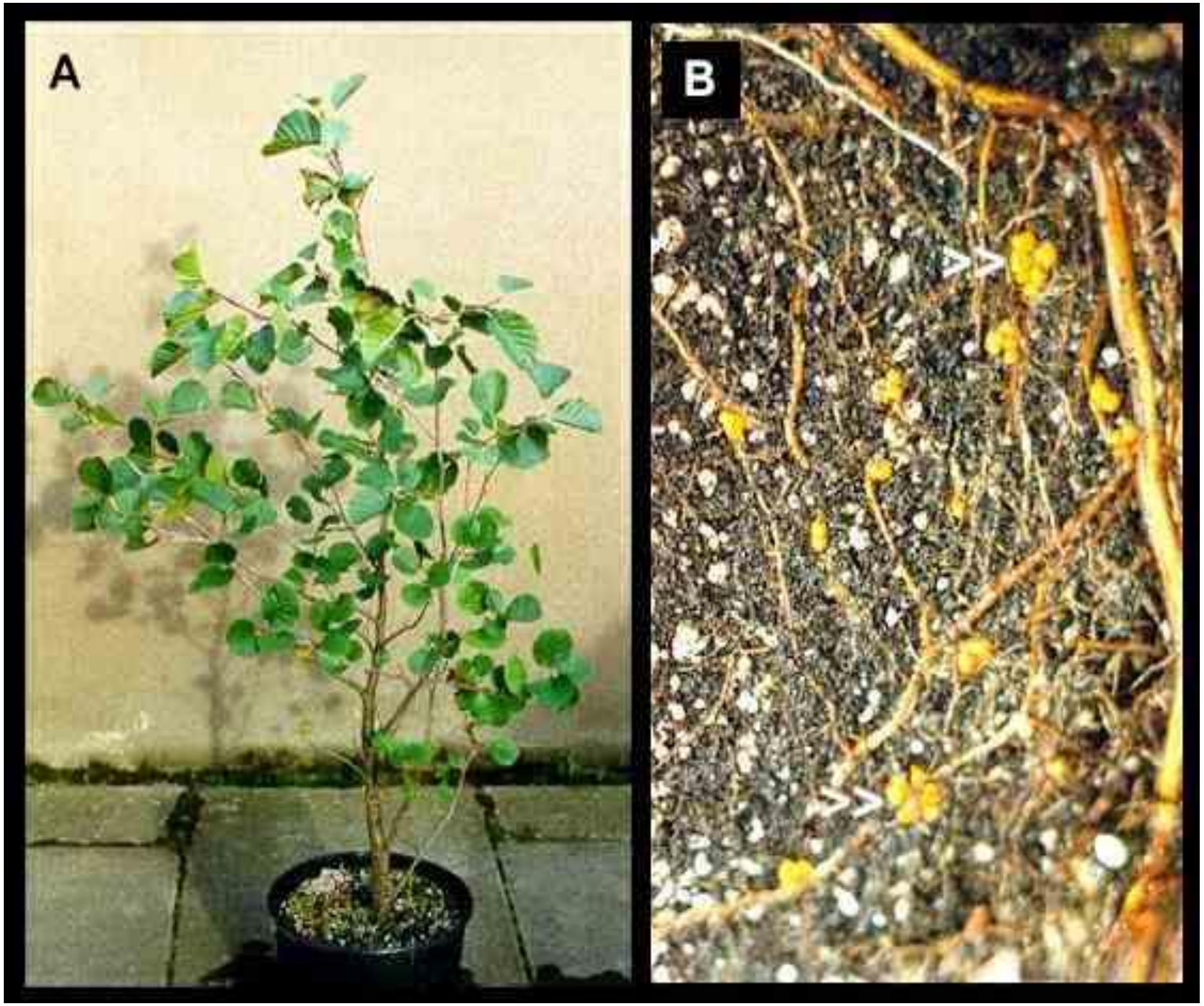


C. When/where does it happen?
N-fixing species are common in early succession

- Lichens early in primary succession following deglaciation in Alaska.
- Alder at later stages.

Red alder in secondary succession following clearcutting near Lake Whatcom

Alder and the other woody hosts of *Frankia* are typical pioneer species that invade nutrient-poor soils. These plants probably benefit from the nitrogen-fixing association, while supplying the bacterial symbiont with photosynthetic products.



d. Paradox of N limitation

- Nitrogen is the element that most frequently limits terrestrial NPP
- N_2 is the most abundant component of the atmosphere
- Why doesn't nitrogen fixation occur almost everywhere?
- Why don't N fixers have competitive advantage until N becomes non-limiting?

Environmental limitations to N fixation

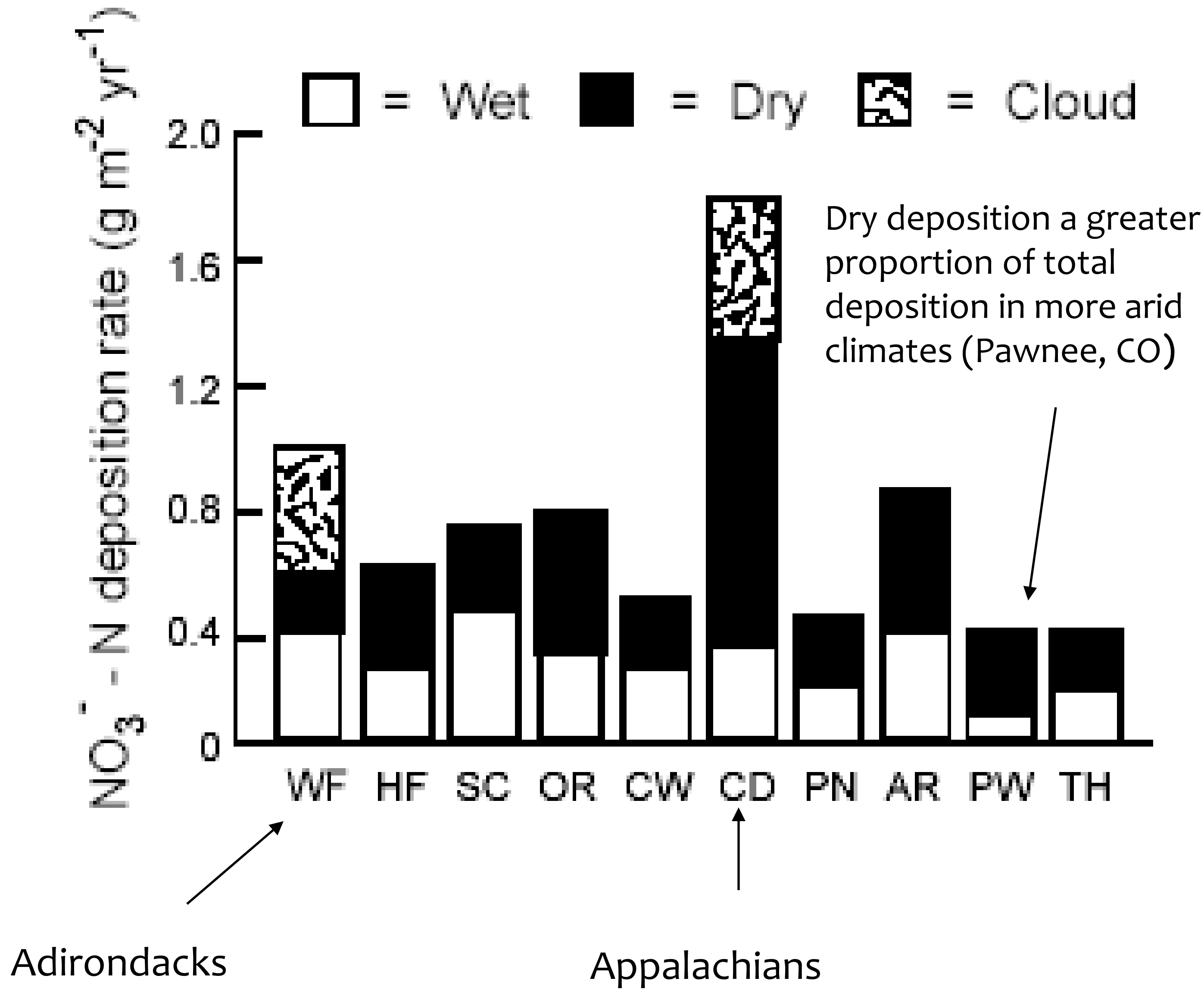
- Energy availability in closed-canopy ecosystems
  - N-fixers seldom light-limited in well-mixed aquatic ecosystems (e.g., lakes)
- Nutrient limitation (e.g., P, Mo, Fe, S)
  - These elements may be the ultimate controls over N supply and NPP
- Grazing
  - N fixers often preferred forage

A. Inputs
2. Nitrogen Deposition

- **Wet deposition**: dissolved in precipitation
- **Dry deposition**: dust or aerosols by sedimentation (vertical) or impaction (horizontal)
- **Cloud water**: water droplets to plant surfaces immersed in fog; only important in coastal and mountainous areas

Wet deposition typically scales with precipitation.

Dry deposition can be significant even in humid climates.



3. Rock weathering as a source of N?

- Some sedimentary rocks contain substantial amounts of N with high rates of N release (up to 2 g-N m^{-2} y^{-1}); however, most rocks contain little N.

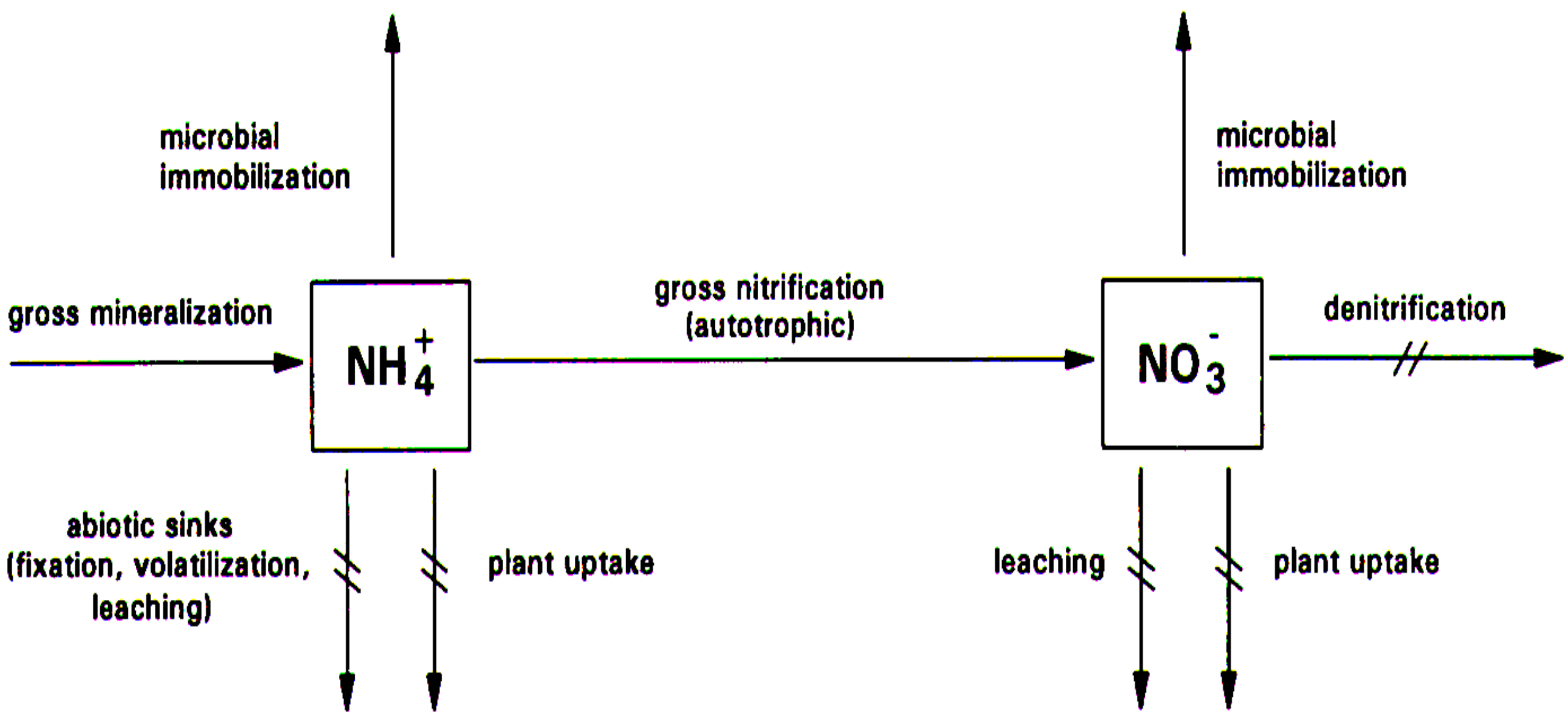
B. Internal Cycling of Nitrogen

- In natural ecosystems, most N taken up by plants becomes available through decomposition of organic matter
  - Over 90% of soil nitrogen is organically bound in **detritus** in a form unavailable to organisms
  - The soil microflora secrete **extracellular enzymes** (**exoenzymes**) such as proteases, ribonucleases, and chitinases to break down large polymers into water-soluble units such as amino acids and nucleotides that can be absorbed

- **Net rates of N transformations** (mineralization and nitrification)

Net N mineralization = Δ (NH_4^+ +NO_3^- pools)

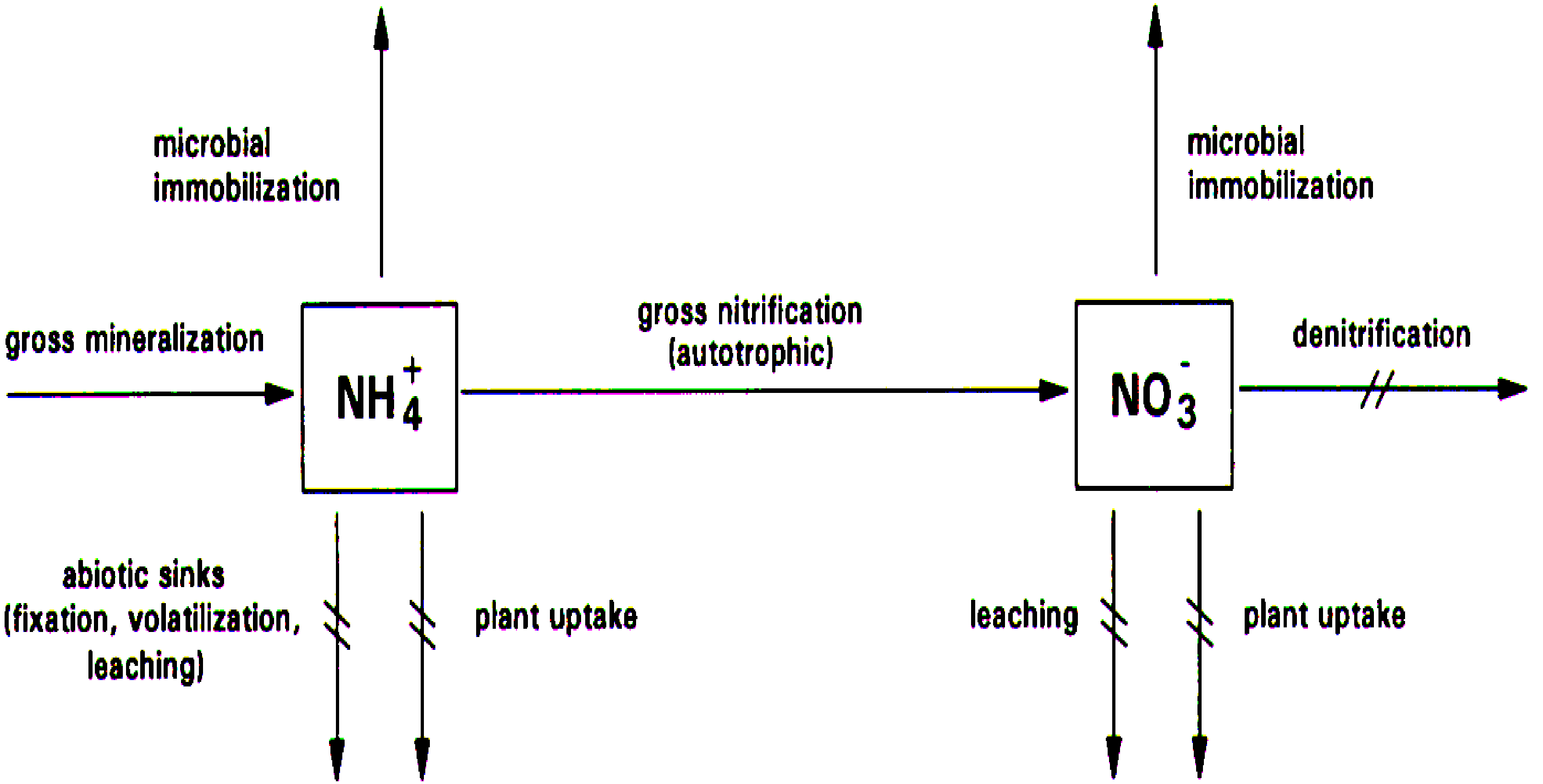
= gross N mineralization-gross N immobilization



- Similarly…

  Net nitrification = Δ NO_3^- pool

  = gross nitrification – gross NO_3^- immobilization



Critical litter C:N for net N min.

- Microbial C:N ~10:1
- Microbial growth efficiency ~40%
- So, for 100 units C, 40 units → mic biomass, 60 units respired.
- For mic C:N of 10:1, need 4 units of N per 40 units C.
- So substrate needs C:N of 100:4 (i.e., 25:1) for net N mineralization.

2. Nitrification
a. Why is Nitrification Important?

- Nitrate is more mobile than ammonium, so more readily leached from soil
- Substrate for denitrification (N loss as a gas)
- Generates acidity if nitrate is lost from soil
- Loss of nitrate results in loss of base cations

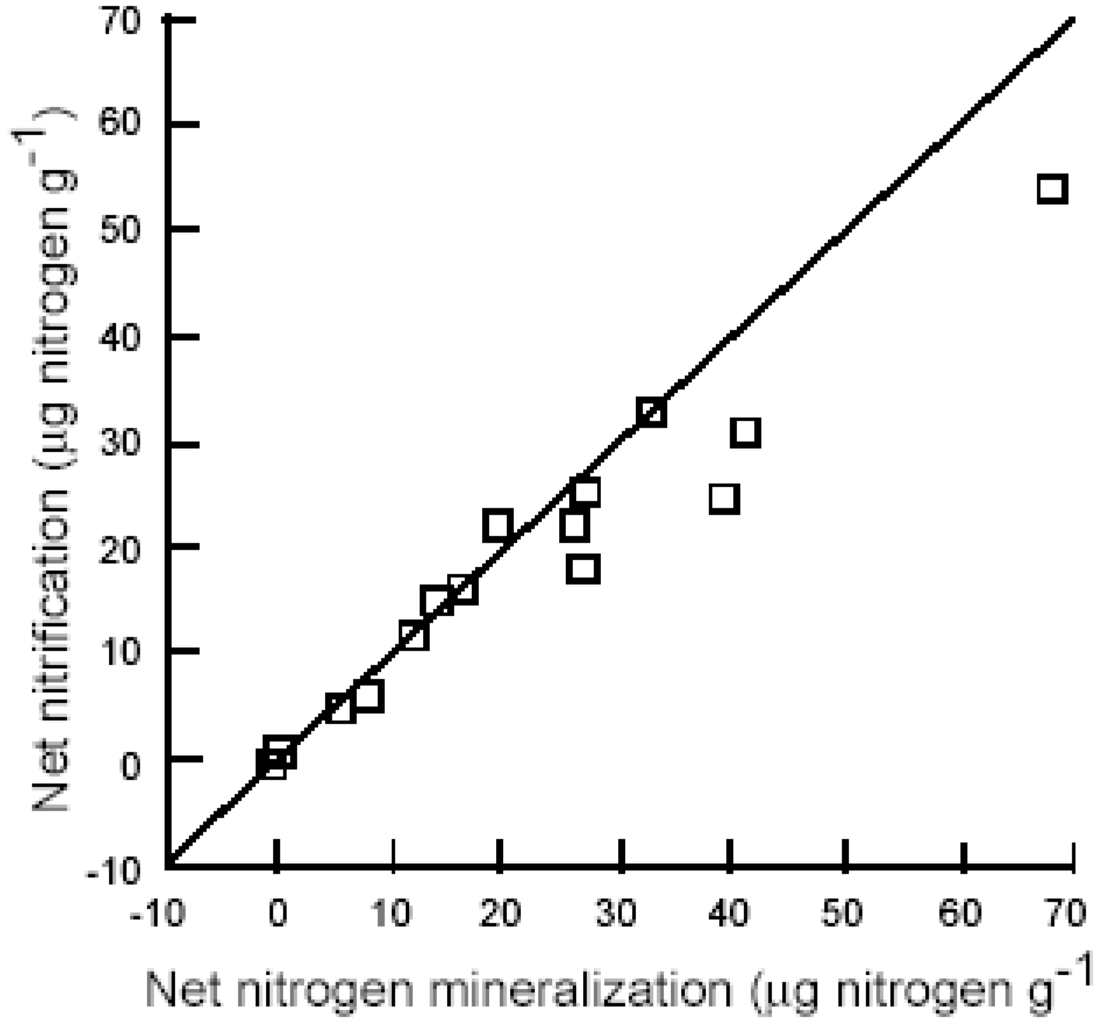
2.b. Controls on Nitrification

- $NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$
  - Two-step process conducted by chemoautotrophic bacteria:
    - First step conducted by *Nitrosomonas* (other Nitroso-), $NH_4^+ \rightarrow NO_2^-$, ammonia mono-oxygenase, need O_2
    - Second step conducted by *Nitrobacter*, $NO_2^- \rightarrow NO_3^-$
  - Controls:
    - NH_4^+
    - O_2
    - Slow growth of nitrifiers

Nearly all nitrogen that is mineralized in these systems is nitrified on a net basis.

-In contrast, net nitrification is frequently less than 25% of net mineralization in temperate coniferous forests.

- Semi-arid forests tend to show more net nitrification relative to net N mineralization



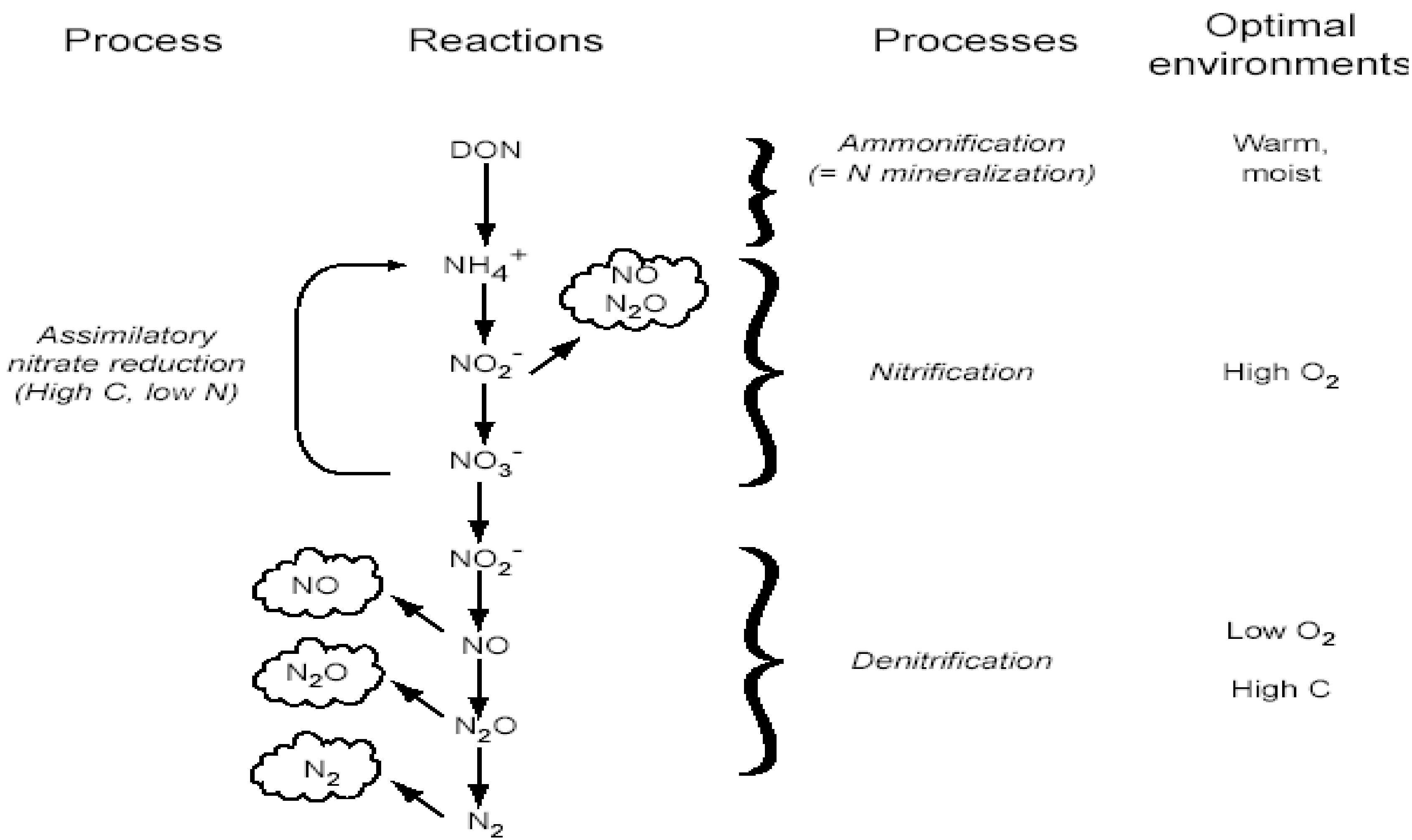
9.6 - The relationship between net nitrogen mineralization and net nitrification (µg nitrogen g-1 of dry soil for a 10-day incubation) across a range of tropical forest ecosystems (Vitousek and Matson 1984).

C. N outputs

1. Gaseous losses

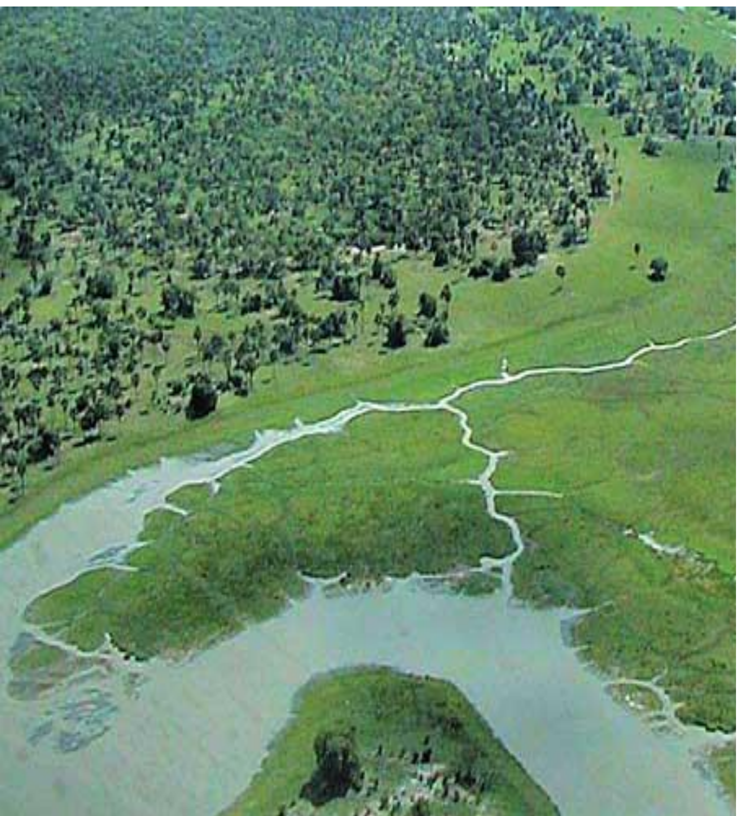
- Ammonia gas (pK = 8.2, $NH_4^+ \rightarrow NH_3 + H^+$)
- Fire
- Oxides of N (NO, N_2O, N_2)
  - **NO** and N_2O from autotrophic nitrification
  - NO, **N_2O, N_2** from denitrification
- Most denitrification conducted by heterotrophic bacteria (many are facultative anaerobes that use NO_3^- as a terminal e^- acceptor in the absence of O_2)
  - Controls: NO_3^-, C availability, O_2,

- Nitrification and denitrification occur under different conditions.
- Gaseous losses for both follow the “hole-in-the-pipe” model.
- H-in-the-P depends on rate of flux and percent of losses.

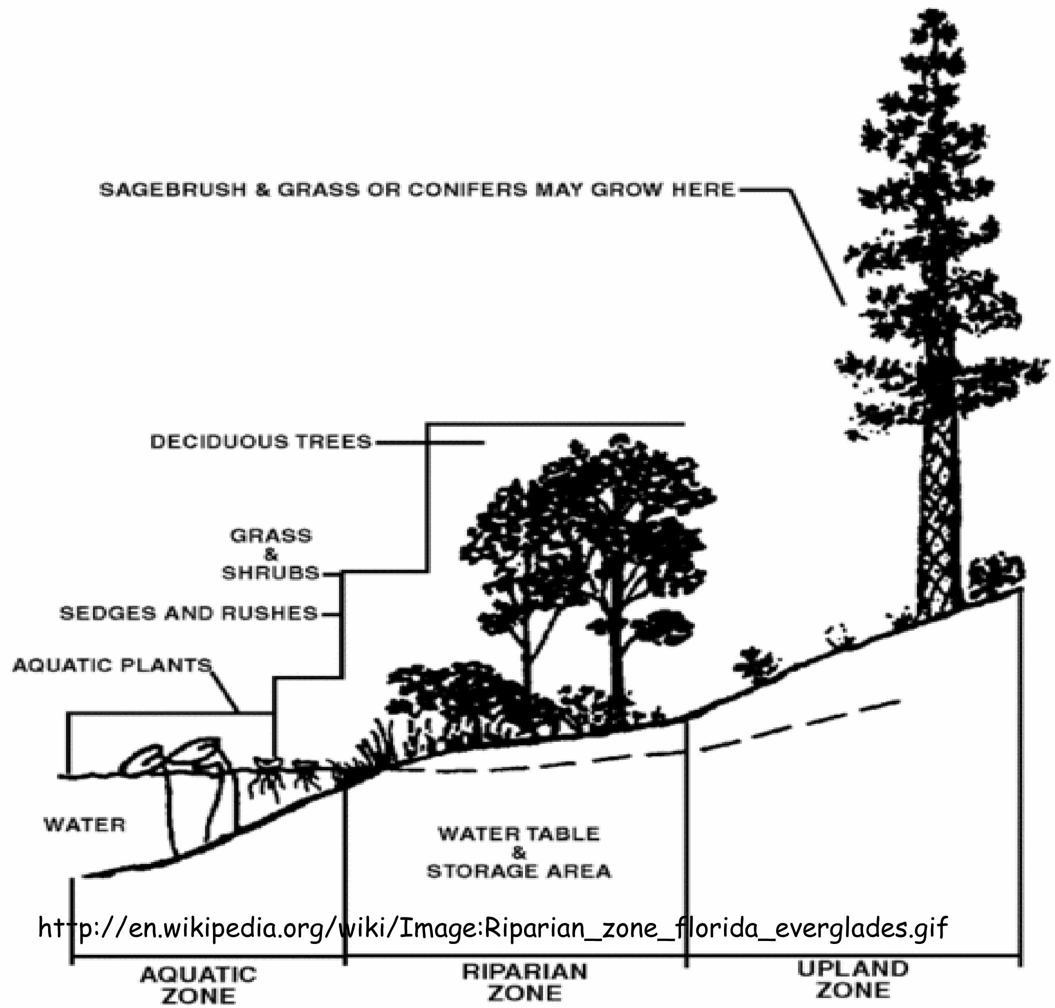


Denitrification – where?

- Very important in wetlands, riparian areas.
- Spatially very patchy in well-drained soils.



http://www.wldelft.nl/cons/area/mse/ecom/im/wetl



http://en.wikipedia.org/wiki/Image:Riparian_zone_florida_everglades.gif

C. N outputs
2. Leaching

- Erosional losses
- Solution losses
  - NO_3^- >> DON >NH_4^+
  - Greatest when water flux is high and biological demand for N is low (e.g., after snowmelt!)

- Leaching losses of nitrate and cations decrease with forest regrowth at Hubbard Brook.
- Plant **and** microbial demand