Nutrient Cycling in Forests

Primarily concerned with limiting nutrients

What is a limiting nutrient?

Plant Nutrients

Structural macronutrients

Other macronutrients

Micronutrients

Ratio of plant constituents-Micro

Ratio of plant constituents-Macro

Ratio of plant constituents
C/N, C/P

Macro Nutrients	Atom Ratio to S	Mass Ratio to S
S	1	1
P	2.00	1.93
Mg	2.67	2.02
Ca	4.17	5.21
K	8.33	10.16
N	33.33	14.56
O	1000.00	498.91
C	1166.67	436.91
H	2000.00	62.99

Limiting Nutrients in Forests

Phosphorous

Main inputs are chemical weathering of parent material

Not very soluble

Easily forms insoluble complexes

Nitrogen

Main inputs are fixation

Ratio	Atoms	Mass
C/N	35.0	30.0
C/P	583.3	226.1

Nutrient cycling occurs primarily in the soil

Phosphorus cycle

Chemical Weathering

Primary input for P

Dissolution of apatite by carbonic acid

•$Ca_5(PO_4)_3 + 4H_2CO_3 \longrightarrow 5\ Ca^{2+} + 3HPO_4^{2-} + 4HCO_3 + H_2O$

Rapidly taken up by organisms

Becomes unavailable

•Binds to organic matter
•Forms insoluble minerals

Essential cations

From dissolution of parent material

Stored on CEC sites

Plants can release cations from CEC sites

Soil "flora"

Autotrophs

- Algae
- Cyanobacteria

Heterotrophs

- Bacteria
- Actinomycetes
- Fungi

Soil bacteria

Smallest & most numerous soil microorganisms

Greater than 1x 10^9 bacteria/ gram soil

More than 400 genera

Estimated 1 x 10^4 species

Efficient converters

Live in a redox world

Crucial to:

Nutrient cycling

Soil structure

Soil flora play crucial roles in nutrient cycles

Direct Effects

Elements with variable oxidation states serve as electron donors/acceptors in microbially mediated transformations

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Indirect Effects

Bacteria & fungi mobilize elements and bioaccumulate

Terrestrial Nitrogen Cycle

Nitrogen Fixation Fluxes

Abiotic

Lightening < 3 x 10^{12}g N/yr

Biotic

Human

•Direct

- Intentional NH_3, HNO_3 60-80 x 10^{12}g N/yr

- Unintentional NO_X, combustion 40-60 x 10^{12}g N/yr

•Indirect

- Agriculture 40 x 1012g N/yr

"Natural" symbiotic

- 100 x 1012g N/yr

Nitrogen enters primarily through biotic fixation

Reduction of N_2 to organic N ($C\text{-}NH_2$)

Why not widespread?

Symbiotic

Free living

Biotic Nitrogen Fixation

Inhibited by high N concentrations in soil

Enzymes require P, Mo, Co, Fe

Link to other nutrient cycles

Availability may limit N-fixation

Important in early successional stages

Declines in mature ecosystems

Why?

Biotic fixation rates

Symbiotic N-fixation nodules

Nitrogen Fixation evolved in an anaerobic environment

Nitrogenase is poisoned by oxygen

All N-fixers use same enzyme system

Must protect from oxygen

Organism	N fixed kg/ha/yr
Free-living	
Cyanobacteria	25
Azotobacter	0.3
Plant/cyano association	
Azolla/rice	313
Lichens	39-84
Legumes	
Soybeans	57-94
Alfalfa	128-600
Lupines	150-169
Nodulated non-legumes	
Alder (*Alnus* & *Frankiella*)	40-300

Symbiotic N-fixation infection of host legume

Free-living N-fixers

Bacteria in soil and wood

Associative fixers

Found near and within plants

Use exudates, secretions, sloughed cells for energy

Within intercellular spaces

Inside vascular tissue

•*Acetobacter diazotrophicus* in sugarcane

Terrestrial Nitrogen Cycle

Ammonification

Decomposition releases ammonium from organic N compounds

C-NH_2 —> NH_4^+

Ammonium pool very transitory

Immobilized into bacteria

Taken up by plants

NH_4^+ is a reduced compound (energy source)

Nitrification

Aerobic process

Chemoautotrophic bacteria

Use e^- from NH_4^+ to reduce carbon (CO_2—> CH_2O)

NH_4^+—> NO_2^-—> NO_3^-

Ammonium—> Nitrite—> Nitrate

Nitrosomonas, Nitrobacter

Happens rapidly

Nitrate rapidly taken up by plants

Why?

Increases soil acidity

Denitrification

Completes cycle, returns N to atmospheric pool as N_2 & N_2O

Anaerobic

Uses NO_3^- as terminal e^- acceptor

Where would you find in forest soils?