

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

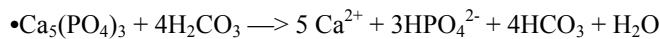
Nutrient cycling occurs primarily in the soil

Phosphorus cycle

Chemical Weathering

Primary input for P

Dissolution of apatite by carbonic acid



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 1×10^9 bacteria/ gram soil

More than 400 genera

Estimated 1×10^4 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 $< 3 \times 10^{12}$ g N/yr

Biotic

Human

•Direct

- Intentional NH_3 , HNO_3 $60\text{-}80 \times 10^{12}$ g N/yr

- Unintentional NO_x, combustion 40-60 x 10¹²g N/yr
- Indirect
 - Agriculture 40 x 10¹²g N/yr
“Natural” symbiotic
 - 100 x 10¹²g N/yr

Nitrogen enters primarily through biotic fixation

Reduction of N₂ to organic N (C-NH₂)

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
<i>Azotobacter</i>	0.3
Plant/cyano association	
<i>Azolla</i> /rice	313
Lichens	39-84
Legumes	
Soybeans	57-94
Alfalfa	128-600
Lupines	150-169
Nodulated non-legumes	
Alder (<i>Alnus & Frankiella</i>)	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

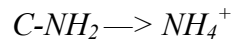
Inside vascular tissue

• *Acetobacter diazotrophicus* in sugarcane

Terrestrial Nitrogen Cycle

Ammonification

Decomposition releases ammonium from organic N compounds



Ammonium pool very transitory

Immobilized into bacteria

Taken up by plants

NH₄⁺ is a reduced compound (energy source)

Nitrification

Aerobic process

Chemoautotrophic bacteria

Use e⁻ from NH₄⁺ to reduce carbon (CO₂ → CH₂O)



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 N₂ & N₂O

Anaerobic

Uses NO₃⁻ as terminal e⁻ acceptor

Where would you find in forest soils?