Forest Nutrition & Biogeochemistry

- Objectives
  - Overview of forest nutrition and biogeochemistry
    - Inputs, internal cycling, and loses of essential nutrients

  - First, thoughts and insights from the reading assignment

Forest Nutrition & Biogeochemistry

- Macro- and micro-nutrients

Table 11.2 Macro-nutrient Elements Required by Plants and their Source within Terrestrial Ecosystems

Element	Symbol	Source
Carbon	C	Atmosphere
Hydrogen	H	Water
Oxygen	O	Atmosphere, water
Nitrogen	N	Organic matter, atmosphere
Phosphorus	P	Mineral soil, organic matter
Potassium	K	Mineral soil, organic matter
Sulfur	S	Mineral soil, organic matter, atmosphere
Magnesium	Mg	Mineral soil
Calcium	Ca	Mineral soil

Source: After Brady (1990).

Table 11.3 The Biochemical Function of Plant Macro-nutrients, their Form of Uptake, and Typical Leaf Concentrations in Plants

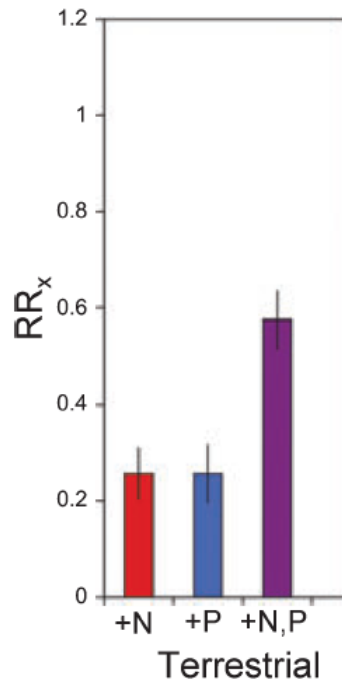
Element	Biochemical Function(s)	Form Assimilated	Leaf Concentration
Carbon (C) Hydrogen (H) Oxygen (O)	Form the basic building blocks of all biologically-active compounds	CO_2, H_2O	90-98%
Nitrogen (N)	Nucleic acids, amino acids, proteins, chlorophyll, anthrocyanins, alkaloids	NH_4^+, NO_3^-	1-4%
Phosphorus (P)	Nucleic acids, nucleitides, sugar phosphates, phospholipids	$H_2PO_4^-$	0.1-0.4%
Potassium (K)	Enzyme co-factor, osmotic regulation, cell ion balance	K^+	1%
Calcium (Ca)	Pectin synthesis and cell wall formation, metabolism/ formation of nucleus and mitochondria, enzyme activator	Ca^{2+}	0.8%
Sulfur (S)	Amino acids, proteins, sulfolipids	SO_4^{2-}	0.2%
Magnesium (Mg)	Chlorophyll, enzyme co-factor	Mg^{2+}	0.2%

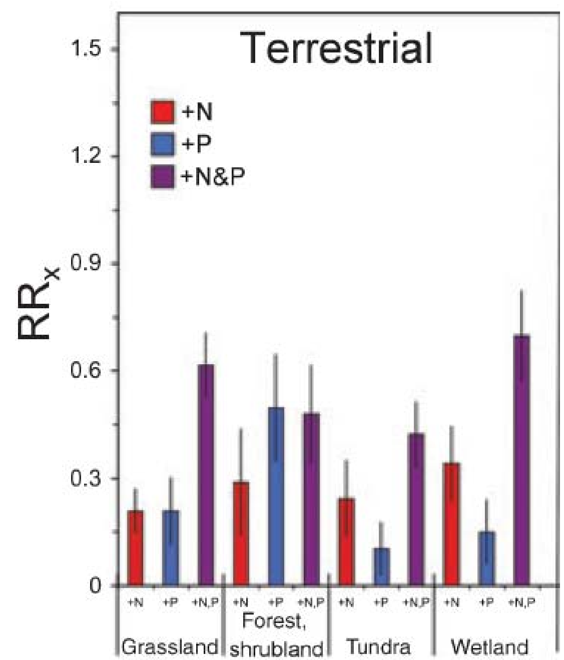
Source: After Salisbury and Ross (1992).

Forest Nutrition & Biogeochemistry

- Nutrient Limitation to Growth

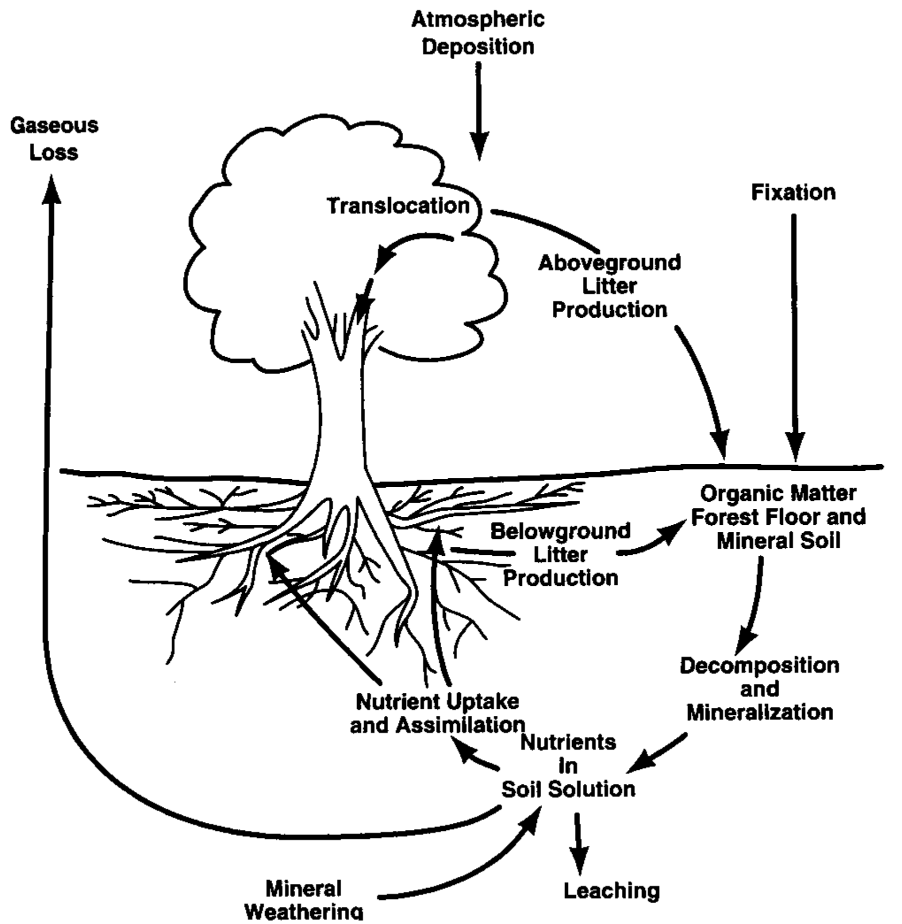
- Meta-analysis (Elser *et al*., 2007)
  - 173 studies
  - % change in NPP with nutrient addition (N, P, and N+P vs. Control)





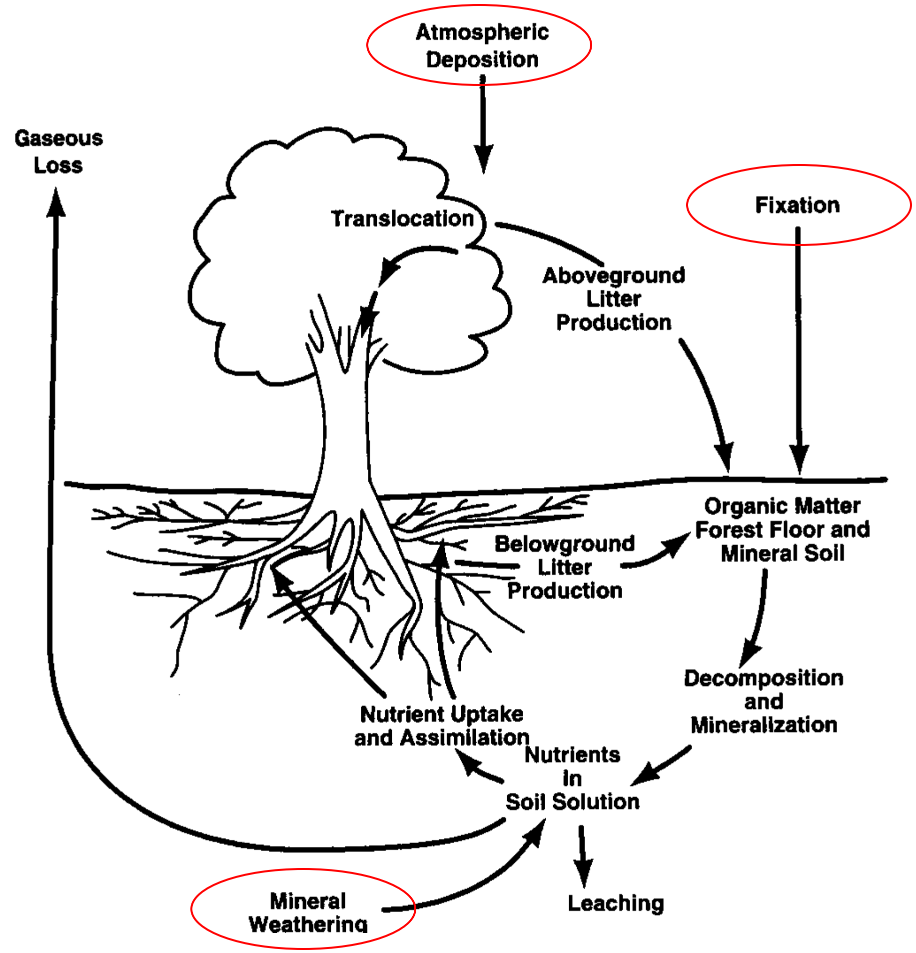
Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Overview



Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Inputs



Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Internal Recycling

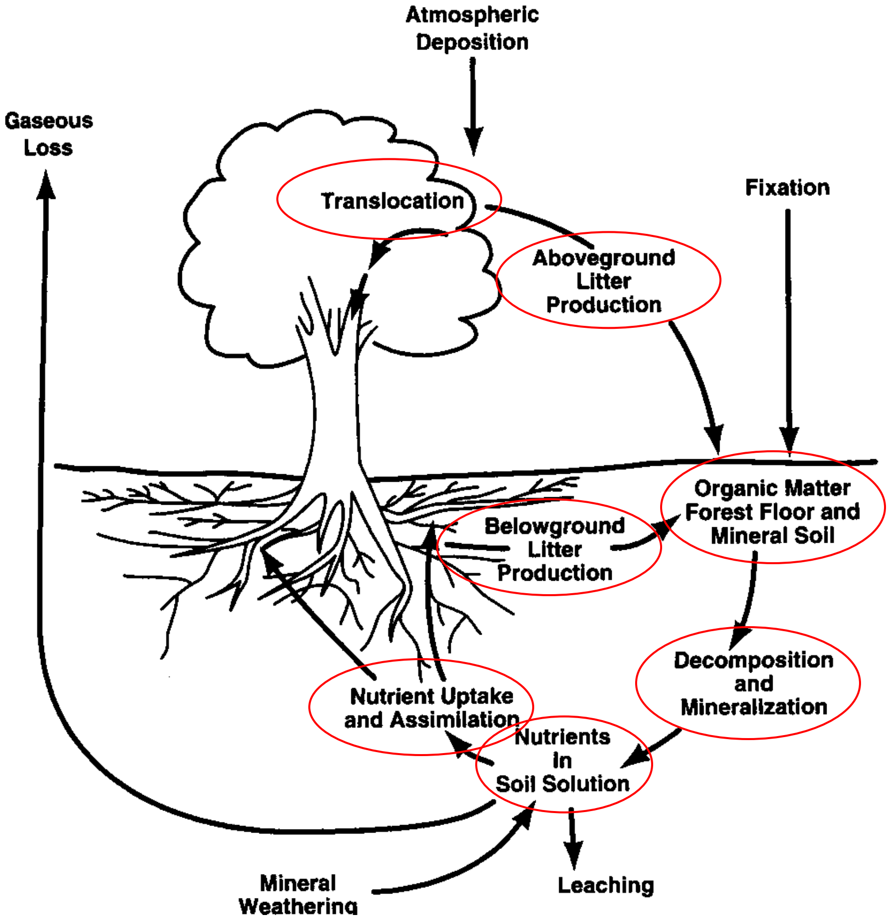


Table 7.1. Major Sources of Nutrients that Are Absorbed by Plants[a].

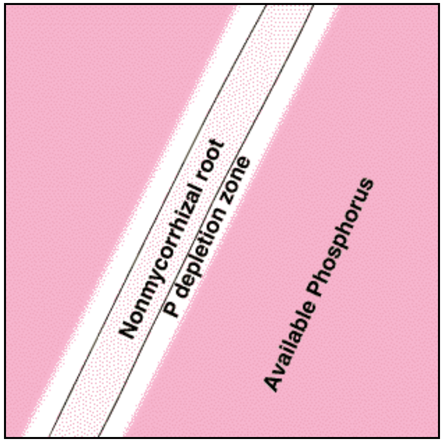
	Source of plant nutrient (% of total)		
Nutrient	**Deposition/fixation**	**Weathering**	**Recycling**
Temperate forest (Hubbard Brook)			
Nitrogen	7	0	93
Phosphorus	1	< 10	> 89
Potassium	2	10	88
Calcium	4	31	65
Tundra (Barrow)			
Nitrogen	4	0	96
Phosphorus	4	< 1	96

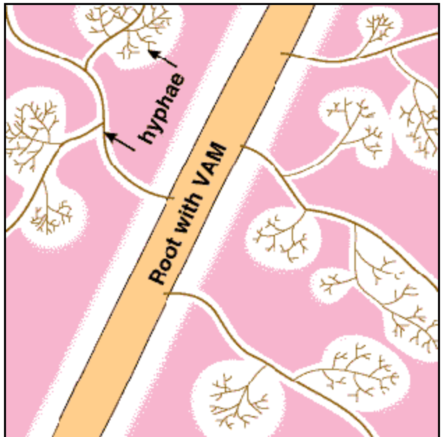
[a] Data from (Whittaker et al. 1979, Chapin et al. 1980b)

Forest Nutrition & Biogeochemistry

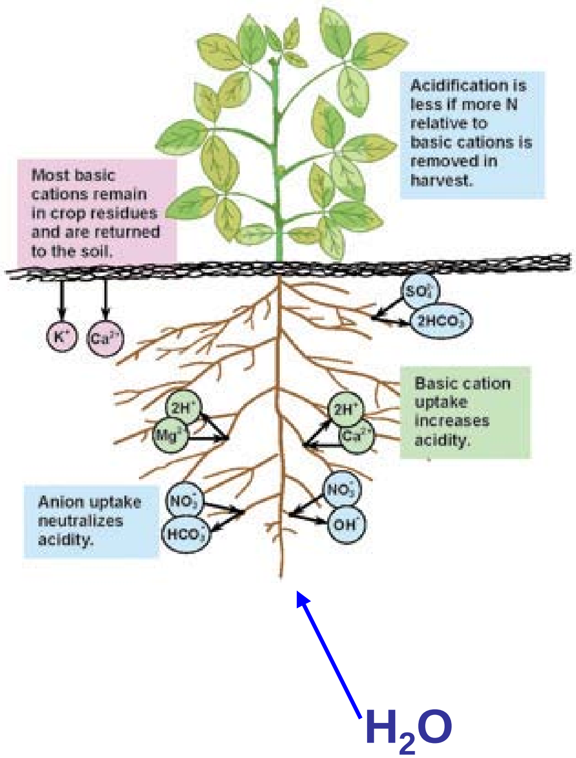
- Nutrient Cycling - Plant Acquisition

Diffusion

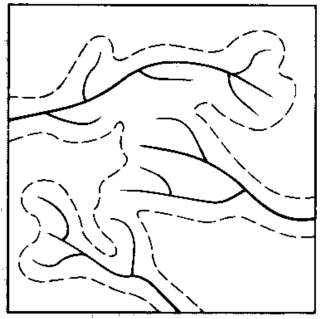


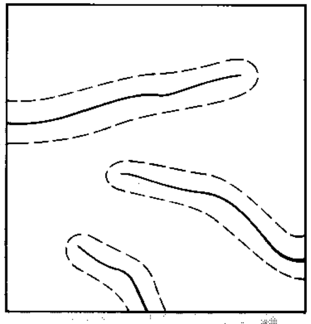


Mass Flow



Root Interception





Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Plant Acquisition

TABLE 8.2. Mechanisms by which nutrients move to the root surface.

Nutrient	Quantity absorbed by the plant ($g\,m^{-2}$)	Mechanism of nutrient supply (% of total absorbed)		
		Root interception	Mass flow	Diffusion
Sedge tundra (natural ecosystem)				
Nitrogen	2.2		0.5	99.5
Phosphorus	0.14		0.7	99.3
Potassium	1.0		6	94
Calcium[a]	2.1		250	0
Magnesium	4.7		83	17

Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Losses

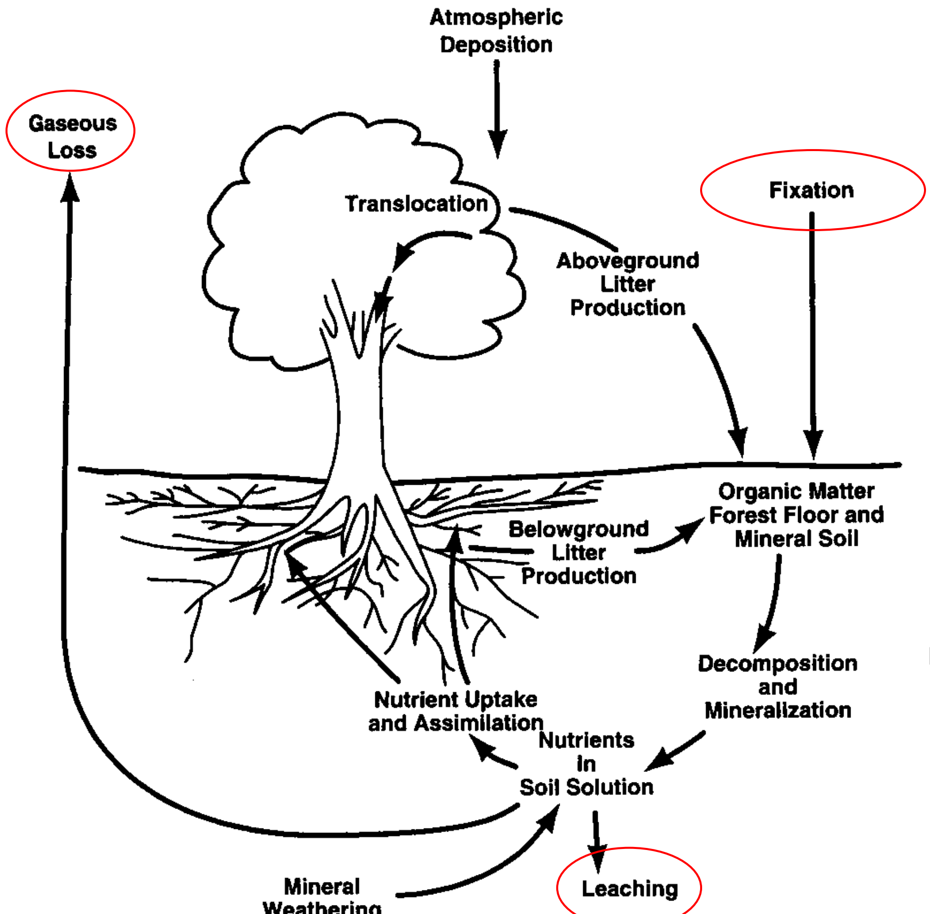
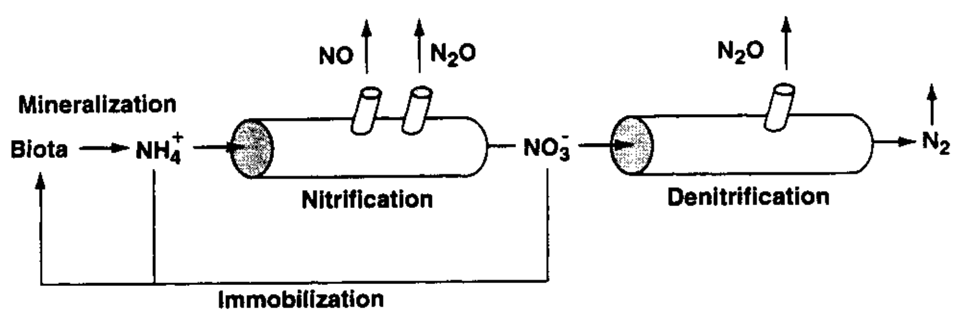


Table 19.8 Nutrient leaching from an intact northern hardwood-dominated watershed in the Hubbard Brook Experimental Forest, New Hampshire.

NUTRIENT	Leaching Loss	Input kg ha^{-1} y^{-1}	Export (−) or Retention (+)
N	4.0	20.7	16.7
P	0.019	0.036	0.017
S	17.6	18.8	1.2
K	2.4	0.9	−1.5
Ca	13.9	2.2	−11.7
Si	23.8	0	−23.8



Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Ecosystem Distribution

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

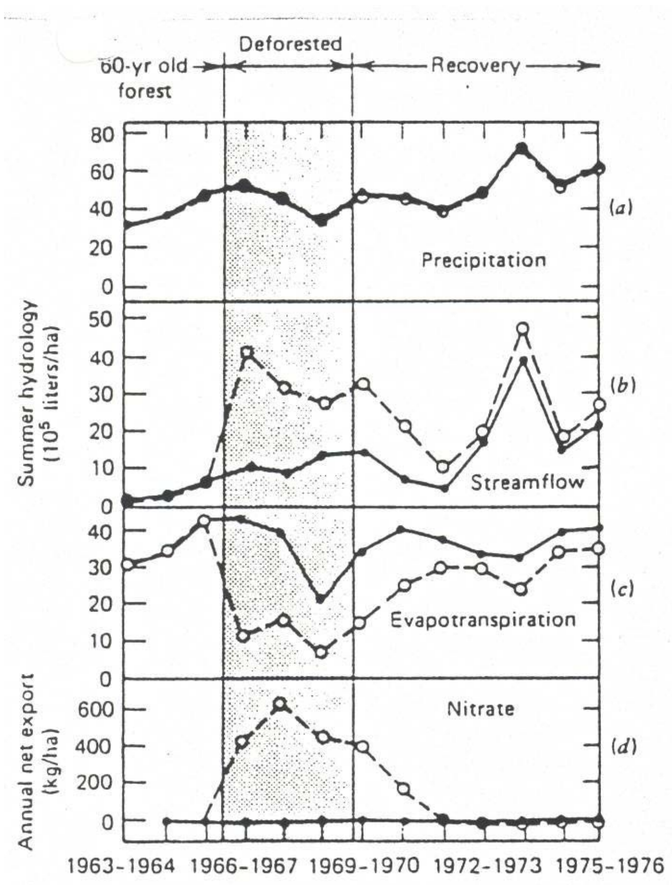
	Boreal	Temperate		Wet Tropical
Location	Alaska USA	Washington USA	New Hampshire USA	Amazon Brazil
Overstory				
Dominant Species	black spruce	Douglas-fir	sugar maple –beech	mixed species[1]
Age (yrs)	95	60	55	mature
Biomass Pools		Mg ha^{-1}		
Overstory	50	410	165	990
Woody Debris	—	9	29	18
Forest Floor	76	15	48	7
Mineral Soil	152	119	173	250
Heterotroph	<1	<1	<4	<1
Total	278	553	419	1265
% in Soil & Litter	**82%**	**24%**	**48%**	**20%**

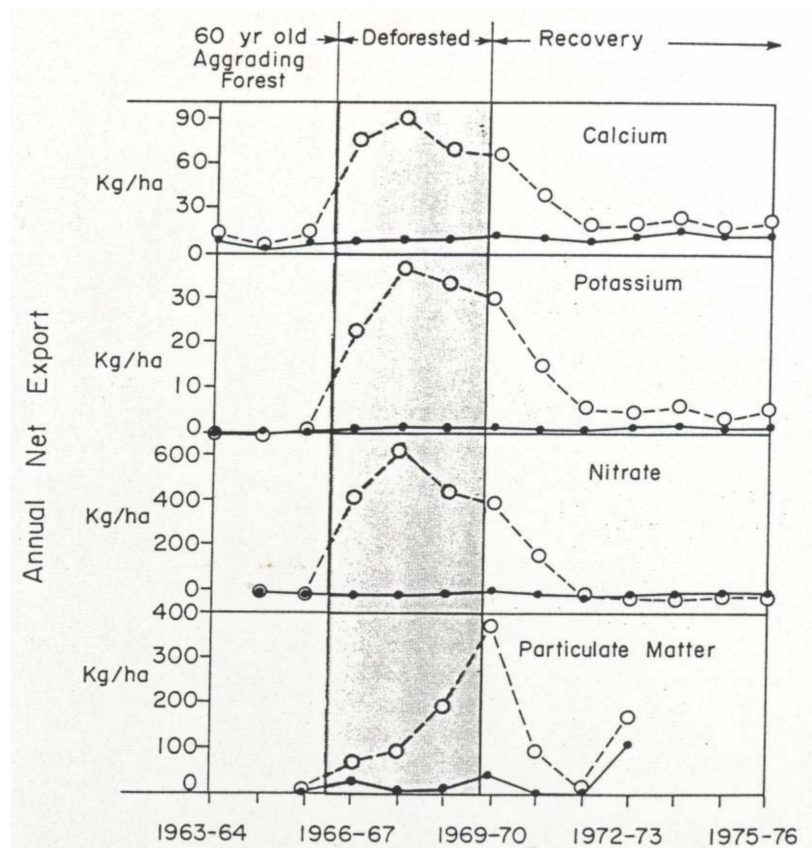
Table 19.9 Distribution of N in tropical temperate, and boreal forest ecosystems.

	Boreal	Temperate			Wet Tropical
Location	Alaska USA	Washington USA	New Hampshire USA	Tennessee USA	Amazon Venezuela
Dominant Species	black spruce	Douglas-fir	sugar maple –beech	oak–hickory	mixed species
Age (yr)	55	42	55	30-80	mature
Nitrogen			kg N ha^{-1}		
Overstory	134	316	491	497	1670
Understory	51	21	9	–	–
Forest Floor	657	233	1100	334	406
Mineral Soil	2200	2476	3600	4500	3507
Total Ecosystem	3042	3046	5200	5331	5583
	94%	**89%**	**90%**	**91%**	**70%**

Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Forest Management





Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Forest Management

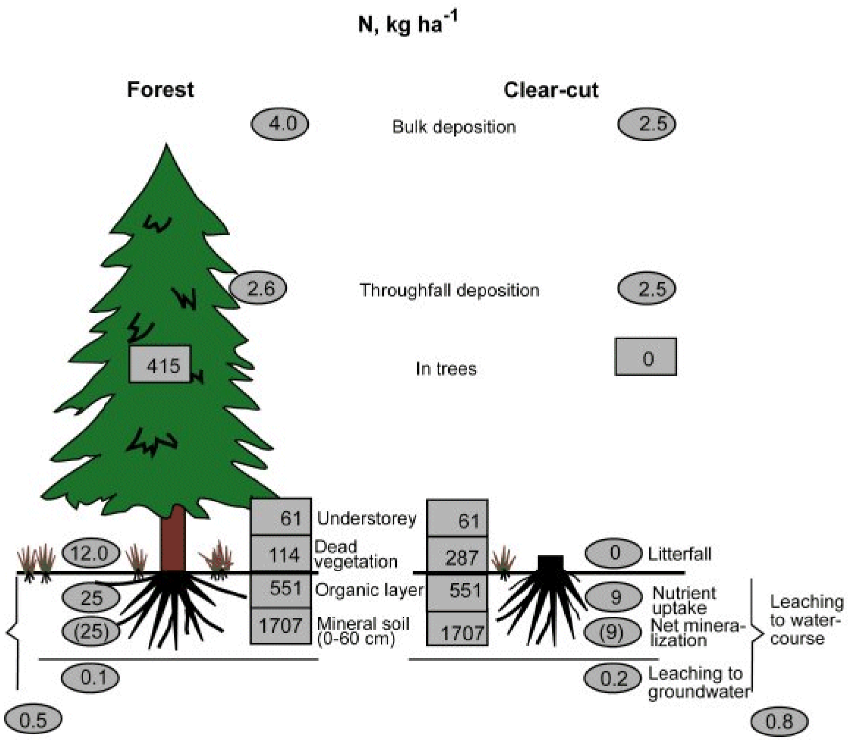
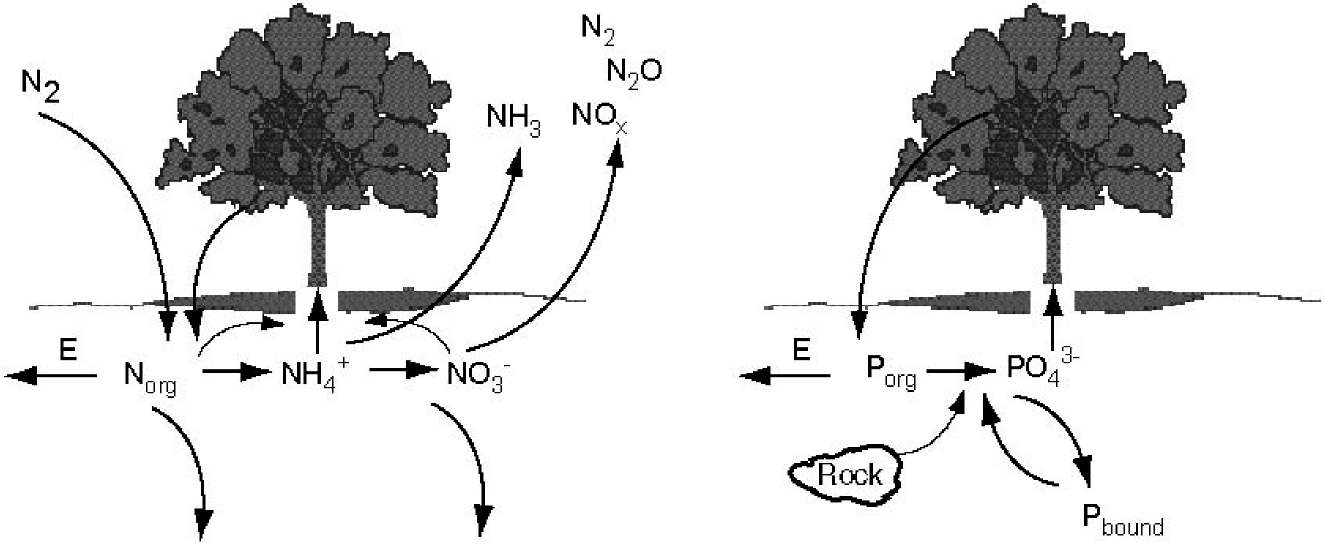


Table 19.11 The nutrient balance for whole-tree harvested trembling aspen ecosystems in northern Minnesota.

	Nutrient N	P	K (kg ha^{-1})	Ca	Mg
Annual Input					
Precipitation	6.9	2.6	9.5	5.0	1.7
Weathering	0	0.4	8.7	20.8	10.4
N_2 Fixation	3.0	–	–	–	–
Ecosystem					
Storage† (kg ha^{-1})	4834.0	147.8	642.5	9081.0	1866.3
Output					
Normal Annual Leaching	0.4	0.6	3.6	28.8	11.3
Accelerated Leaching*	0	0	0	62.3	0
Removal in Biomass	452.0	43.1	354.6	1034.0	94.5
Years to Replenish Harvest Losses§	48	18	24	–#	118

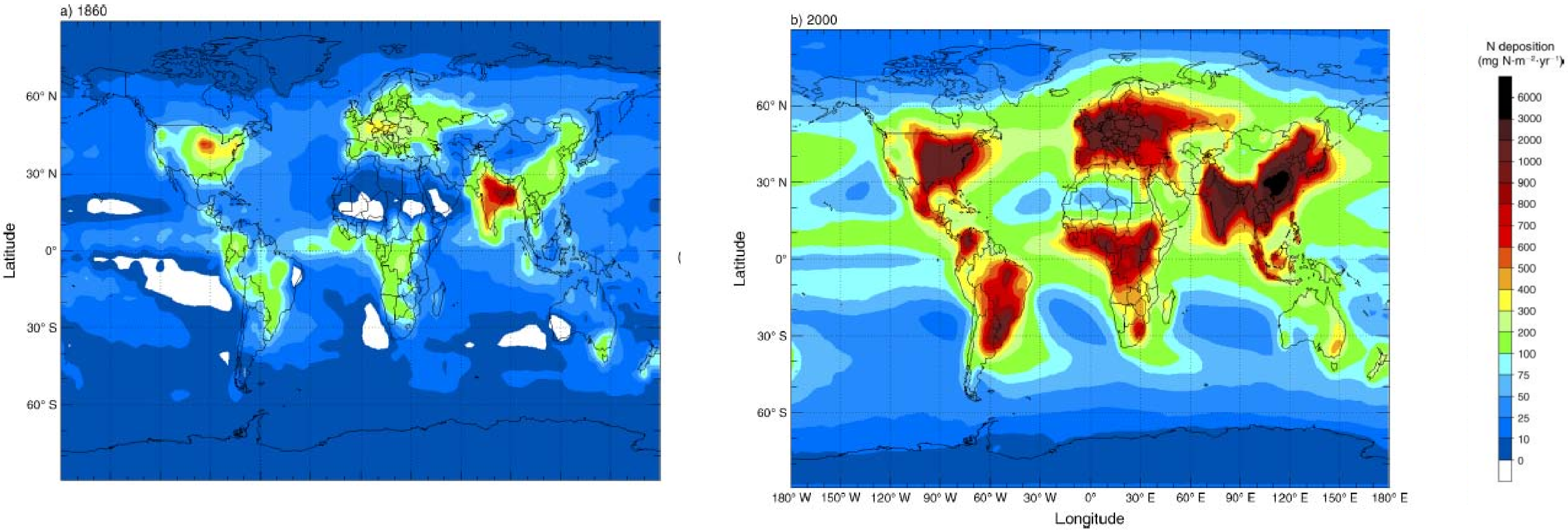
Forest Nutrition & Biogeochemistry

- Nutrient Cycling - N vs. P Biogeochemistry



Forest Nutrition & Biogeochemistry

- Nutrient Cycling - Human Impacts



Bobbink et al. (2010)

Forest Nutrition & Biogeochemistry

- Forest Management
  - Trees require a suite of macro- and micro-nutrients to grow
  - Management activities can adversely impact nutrient "capital"
  - Management can also minimize nutrient loss, or even increase nutrient supply if done properly
  - Sustainable management of SOM, and the nutrients contained therein, is crucial to nutrient cycling

Site nutrient management and site organic matter management must become a major component of sustainable forest management systems (Kimmins 2004).