Biogeochemical cycles of nutrients

- ✓ *Nutrients move through the ecosystem in biogeochemical cycles. A biogeochemical cycle is a circuit/pathway by which a chemical element moves through the biotic and the abiotic factors of an ecosystem. It is inclusive of the biotic factors, or living organisms, rocks, air, water, and chemicals.*

- ✓ *A biogeochemical cycle or inorganic-organic cycle is a circulating or repeatable pathway by which either a chemical element or a molecule moves through both biotic ("bio-") and abiotic ("geo-") compartments of an ecosystem.*

Principles and definitions

- ✓ The cycling of minerals through forest ecosystems is closely linked with those of water and carbon.
- ✓ Precipitation washes minerals from the atmosphere and deposits them on leaves and other surfaces.
- ✓ Water carries dissolved minerals into the soil where they are taken up by roots and transported in the transpiration stream.
- ✓ Water also carries minerals out of the system through erosion and by leaching.
- ✓ Plants respire carbon obtained through photosynthesis to convert minerals from elemental to biochemical forms, and to recycle nutrients internally from older to newer tissues.
- ✓ Heterotrophic and symbiotic organisms rely on carbon supplied from roots and that extracted from detritus to acquire their energy supply and nutrients.
- ✓ Low molecular weight acids produced as metabolic products enhance the release of additional minerals from soil and rock.
- ✓ Other products of microbial decomposition contribute to the accumulation of soil humus.

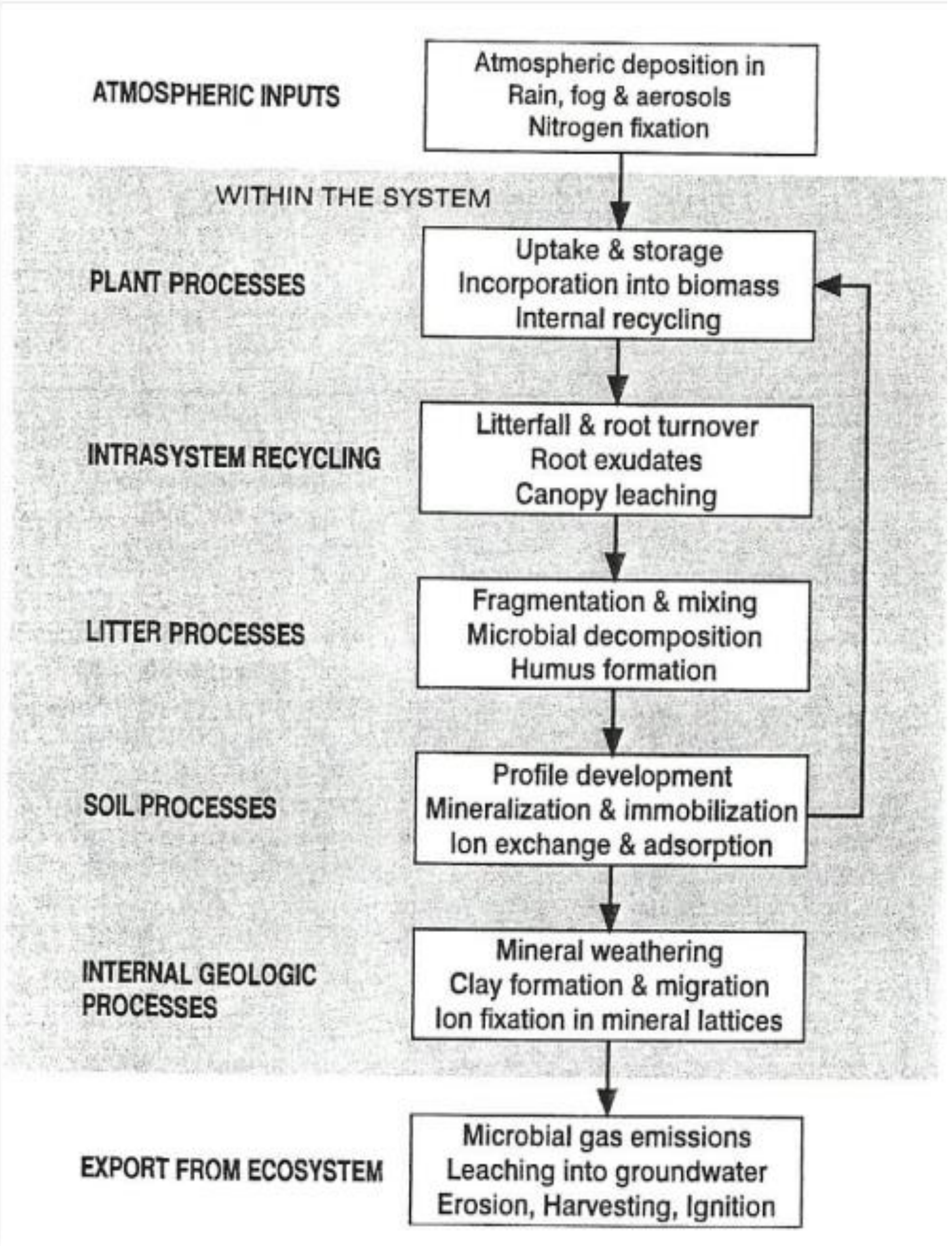

Figure 6.1 Minerals that cycle through a forest ecosystem have variable sources. Many are sequestered from the atmosphere; others are derived from geologic weathering of minerals. Plants modify the cycling of many elements through their selective uptake, internal redistribution, and the fraction returned annually to the forest floor. Litter on the forest floor is utilized by many soil organisms, but eventually a small fraction accumulates as soil humus. During the decomposition process, minerals are converted from organic to inorganic forms. Whether the elements are immobilized in microbial biomass, made available on soil exchange sites, adsorbed to clay surfaces, or fixed permanently into mineral lattices depends on a variety of soil and geologic processes that differ within the soil profile. Eventually some minerals are again taken up by plants and recycled through the system, while others may be lost as gases or in leachate (Waring, Runnig 1998).

Essentials elements

- ✓ The principal elements of life are carbon, hydrogen, oxygen, and nitrogen.
- ✓ all plants require certain macronutrients.
- ✓ Nitrogen (N) is a major constituent of proteins, nucleic acids, and chlorophyll.
- ✓ phosphorus (P) is most important as a component of the energy currency in biochemical reactions.
- ✓ sulphur (S) is found in many amino acids.
- ✓ Specific roles are known for potassium (K) in controlling stomatal function and the charge balance across plant membranes.
- ✓ calcium (Ca) as a constituent of cell walls, and for magnesium (Mg) in chlorophyll.
- ✓ These nutrients also stimulate the rate of various enzymatic reactions.
- ✓ The micronutrients iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn) are widely involved as coenzymes.

Source and uptake of nutrients

Under field conditions, the concentration of nutrients in the soil solution is reduced during the period of exponential plant growth:

- ✓ Nutrients are supplied to plant root surfaces through three mechanisms:

(1) the growth of roots and mycorrhizae into the soil.
(2) the mass flow of ions with the movement of soil water as a result of transpiration.
(3) the diffusion of ions toward the root surface when uptake rates exceed supply.

- ✓ The relative mobility and concentration of nutrients in soil solution and the rate of plant uptake determine which of these mechanisms predominates.

- ✓ Uptake of Ca is often the result of the interception of ions in newly exploited soil zones.

- ✓ Plant demand for N, P, and K often exceeds delivery by mass flow, such that diffusion is the dominant process that supplies these macronutrients .

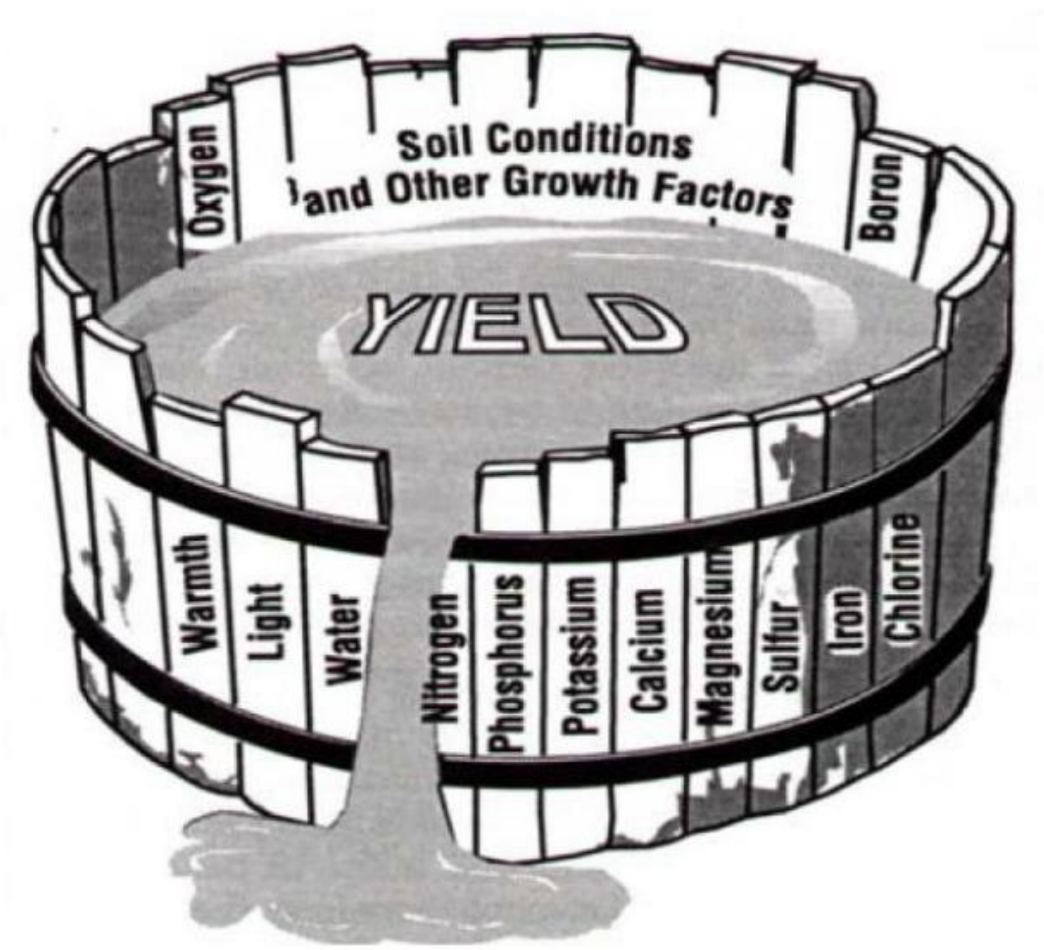

Figure 6.2. Principles of plant nutrition - "law of limiting factors". (Source: http://www.agronomy.ksu.edu/extension/doc2146.ashx).

From Air

Carbon (C)
Oxygen (O)

From Water

Hydrogen (H)
Oxygen (O)

Mineral Nutrients From Soil

Primary Nutrients	Secondary Nutrients	Micronutrients	
Nitrogen (N)	Calcium (Ca)	Boron (B)	Manganese (Mn)
Phosphorous (P)	Magnesium (Mg)	Chlorine (Cl)	Molybdenum (Mo)
Potassium (K)	Sulfur (S)	Copper (Cu)	Zinc (Zn)
		Iron (Fe)	Nickel (Ni)

Figure 6.3. Source of plant nutrients.
(Source: http://www.agronomy.ksu.edu/extension/doc2146.ashx).

Cation: (+)	A Positively Charged Ion
Anion: (-)	A Negatively Charged Ion

Cations in Soil		NUTRIENTS	Anions in Soil	
K^{+}	Potassium		NO_3^{-}	Nitrate
NH_4^{+}	Ammonium		SO_4^{-2}	Sulfate
Mg^{+2}	Magnesium		$H_2PO_4^{-}$ HPO_4^{-2}	Phosphate
Ca^{+2}	Calcium		Cl^{-}	Chloride
Mn^{+2}	Manganese		BO_3^{-2}	Borate
Zn^{+2}	Zinc		MoO_3^{-2}	Molybdate
		NON-NUTRIENTS		
Na^{+}	Sodium		OH^{-}	Hydroxyl
H^{+}	Hydrogen*		$H_2CO_3^{-}$	Bicarbonate
Al^{+3}	Aluminum		CO_3^{-3}	Carbonate

* Hydrogen as a nutrient is obtained primarily from water. H+ ions in the soil affect soil pH and many chemical and biological processes.

Storage and interval recycling

- ✓ The optimum balance of nutrients is determined experimentally by varying nutrient concentrations in hydroponic solutions or sand cultures and observing the relative concentrations found in plants with maximum growth rates.

- ✓ At maximum growth rate the balance of nutrients in solution and those in leaf tissue are the same .

- ✓ The optimum nutrient balance differs only slightly among tree species when referenced to nitrogen content .

- ✓ Total plant nutrient contents reflect long-term nutrient uptake but tell us little about seasonal nutrient circulation.

- ✓ Mature foliage and other organs may exhibit relatively stable ratios of nitrogen with other elements, but this balance is often accomplished through internal reallocation. Reallocation of nutrients from twigs and older foliage helps sustain rapid shoot elongation when root uptake is inadequate to meet the demand.

Return in litter and leachate

- ✓ Return of nutrients in litterfall is the major route of recycling from vegetation to soil.
- ✓ Aboveground litterfall can be measured through periodic collection, weighing, and chemical analysis of twigs, leaves, fruits, and other products that fall into nets or trays positioned just above the ground surface.
- ✓ Annual additions of coarse woody debris can be estimated by recording the amount that fall across string lines laid out annually in a large grid under a forest canopy.
- ✓ Nutrient return in litterfall can vary seasonally from year to year depending on forest composition and the leaf abscission process.
- ✓ In a temperate deciduous forest, found that premature abscission of leaves in summer storms resulted in a small amount of litterfall with relatively high nutrient concentrations because nutrient reabsorption had not occurred.

Forest floor, soil and decomposition processes

- ✓ The soil in forest ecosystems usually consists of a number of layers, or horizons, that collectively comprise the complete soil profile.
- ✓ Recognition of the processes that occur in these horizons is an essential part of understanding nutrient cycling in forest ecosystems.
- ✓ A characteristic property of forest soils is a nearly permanent cover of leaf litter and woody debris.
- ✓ Beneath this surface organic layer, distinct soil horizons usually develop with different chemical, physical, and biological properties.
- ✓ Humans have altered the development of soil horizons by changing the natural sequence of disturbance, the kinds of plants, animals, and microbes present, and the nutrient capital in forest soils.
- ✓ The basic processes, however, remain the same by which nutrients are made available in the soil, taken up by plants, and eventually returned in organic residues.