Nutrient Cycling

Essential for all life

& its availability (or lack thereof) controls the distribution of flora and fauna

Its availability is controlled by 3 things

1. Sources
2. Sinks (pools)
3. Fluxes

For use by organisms, nutrients must be in a specific form –

each to its own…

The largest sinks of nutrients are generally unavailable to organism,

But there is a large group of specialized organisms that can transform this “unavailable” pool to usable form – and thus make it available for all organism.

Much of this transformation of nutrients is controlled by soil characteristics!

The Nitrogen Cycle

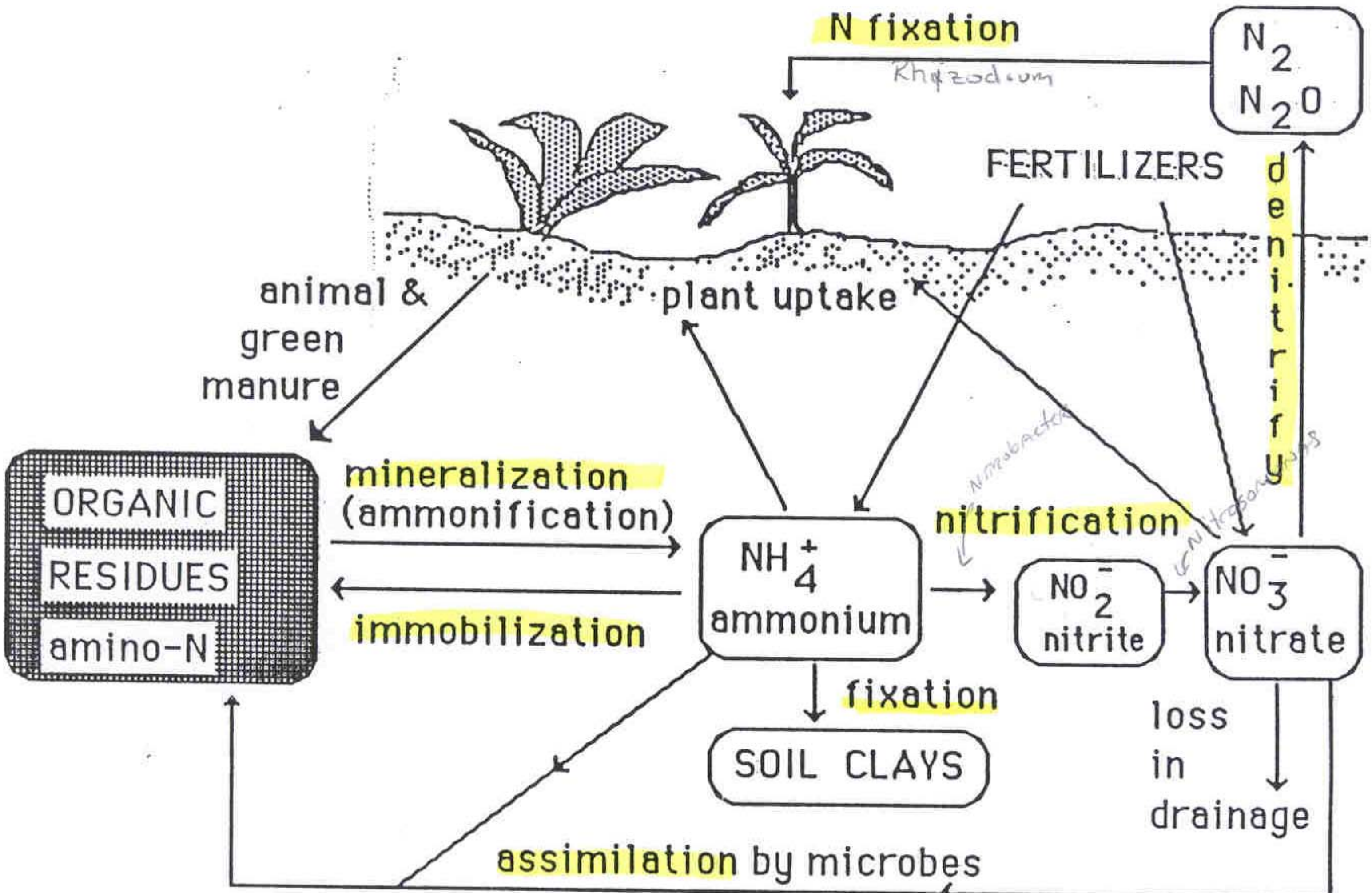
Three questions to think about

- What are the pools
- What are the sources and losses
- What are the fluxes

Then think about what controls these…

NB ~ flux rates and pools are controlled by edaphic environmental conditions, while N sources are often global in nature!

In the soil environment, what controls N?



1. Sources

   a. humans – atmospheric deposition, inorganic fertilizer, waste, etc…

   b. microorganisms – N fixation (symbiotic and non-symbiotic)

   c. stochastic events – lightning and fire

2. Sinks

   a. atmosphere – 386 x 10^{16} kg

   b. biomass – 0.045 x 10^{16} kg

   c. soil – 0.024^{16} x 10 kg

3. Fluxes

   a. immobilization ↔ mineralization (ammonification and nitrification)

   b. denitrification

   c. fixation – N fixation (biological and abiotic) and NH_4^+ fixation (colloids)

   d. plant uptake

   e. leaching and volatilization

Sinks

a. atmosphere – 386 x 1016 kg
b. biomass – 0.045 x 1016 kg
c. soil – 0.02416 x 10 kg

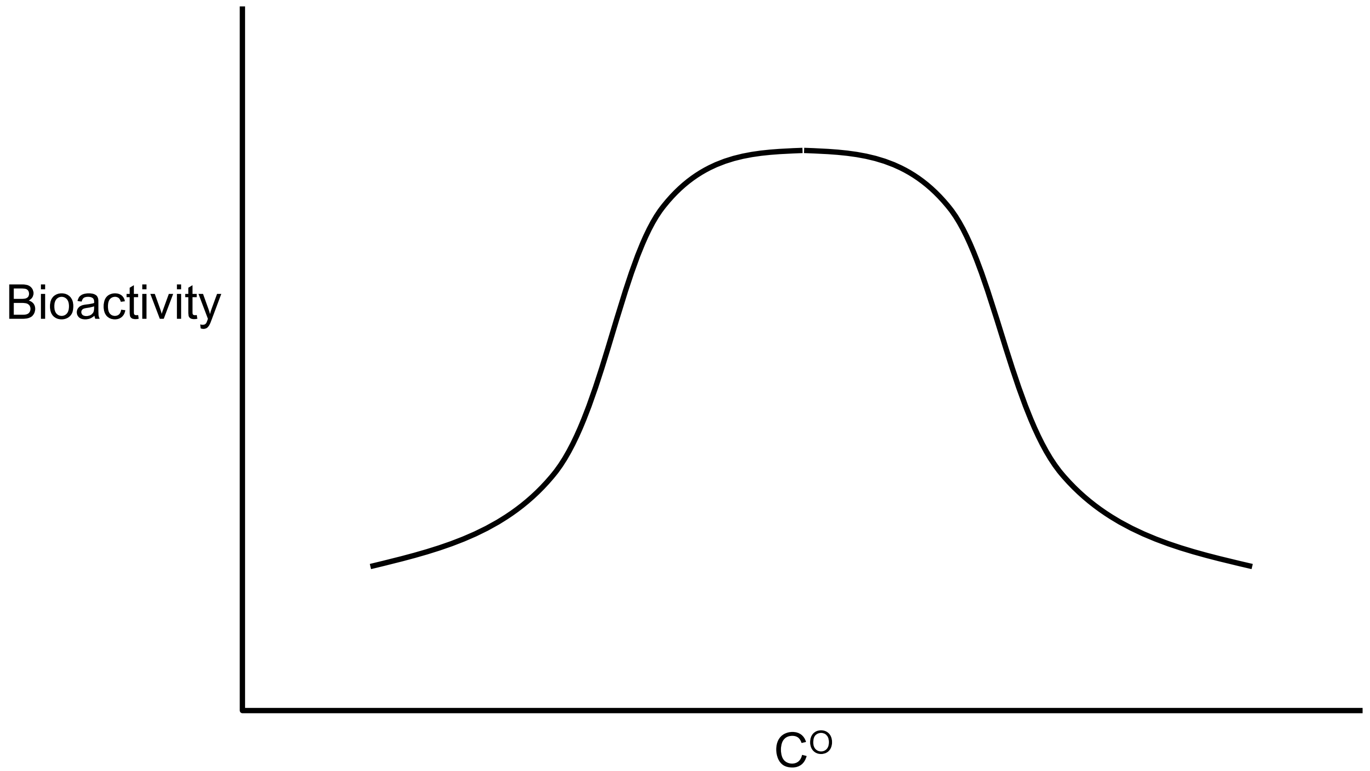
Fluxes

a. immobilization ↔ mineralization (ammonification and nitrification)
b. denitrification
c. fixation – N fixation (biological and abiotic) and NH_4^+ fixation (colloids)
d. plant uptake
e. leaching and volatilization

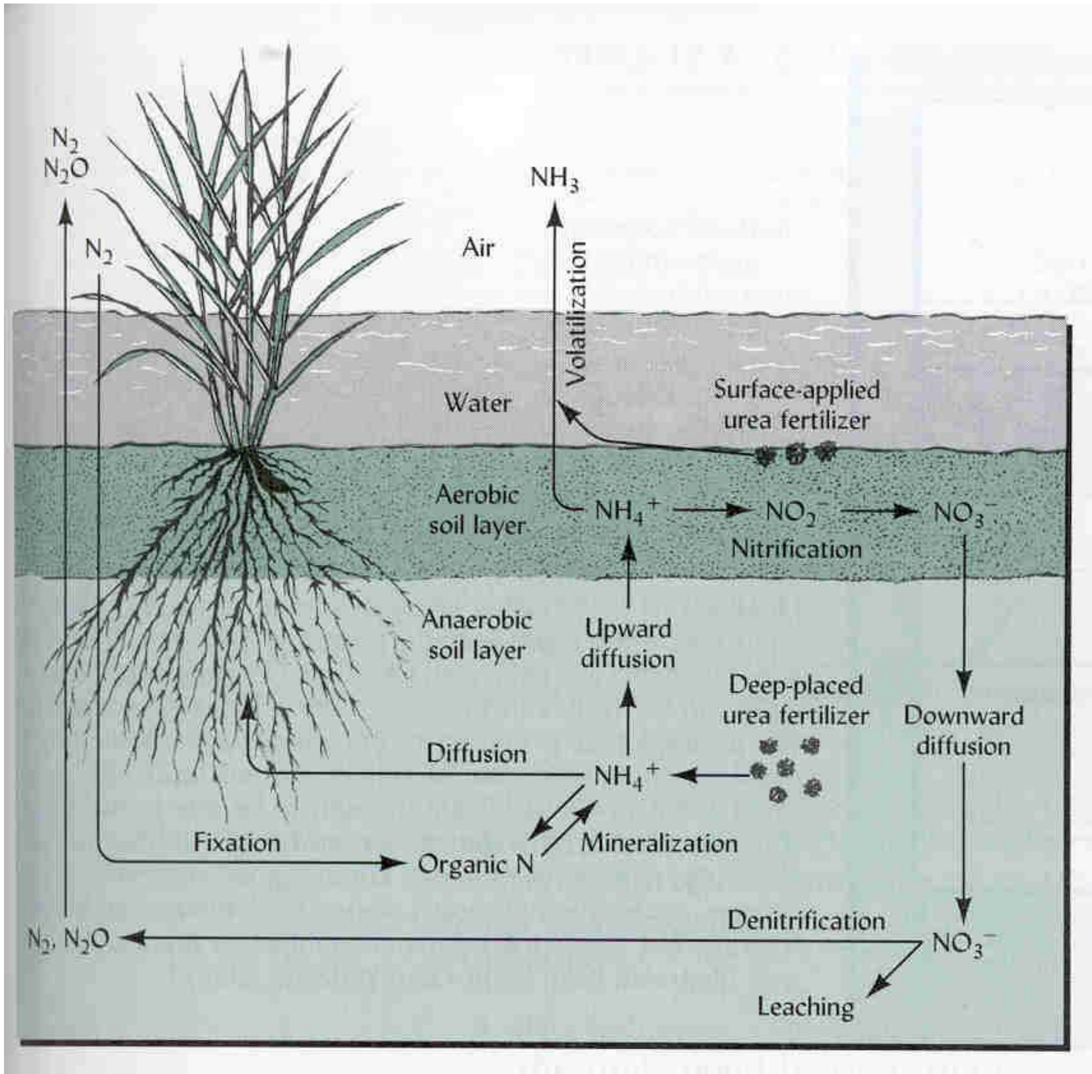
What controls these fluxes in the soil?

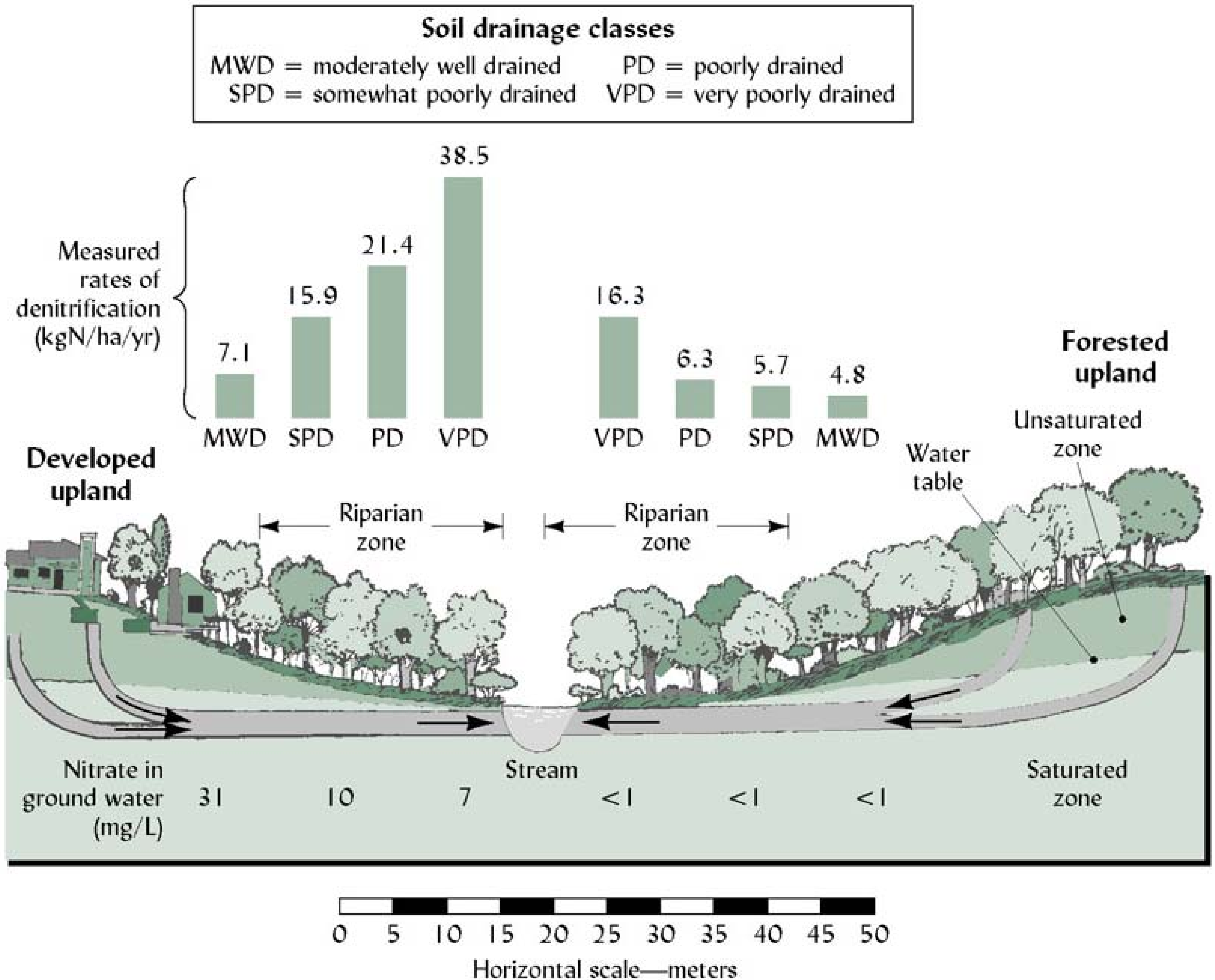
Temperature
Moisture
Oxygen
Nitrogen

Temperature

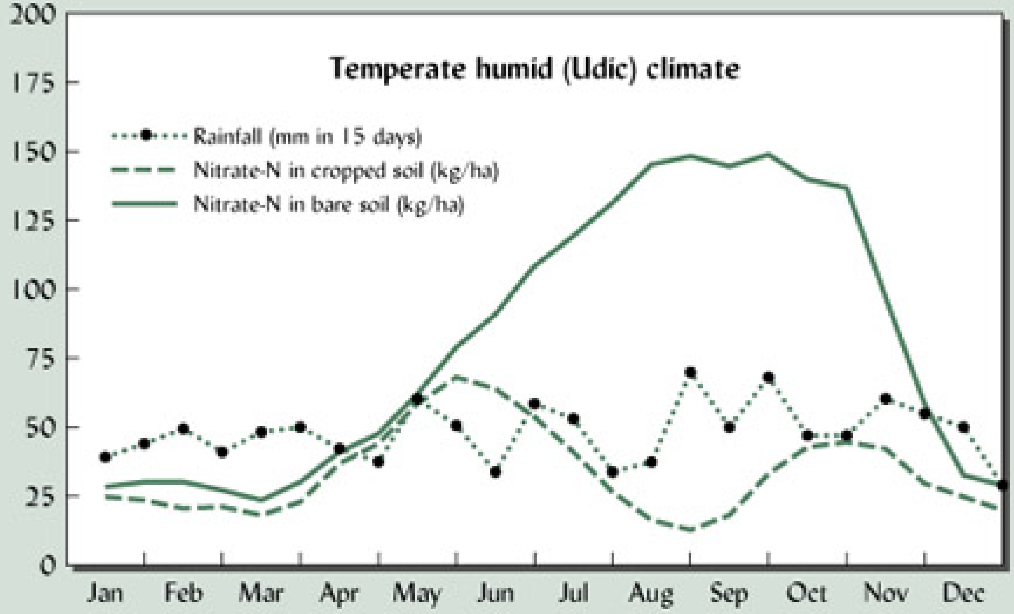


Moisture & Oxygen

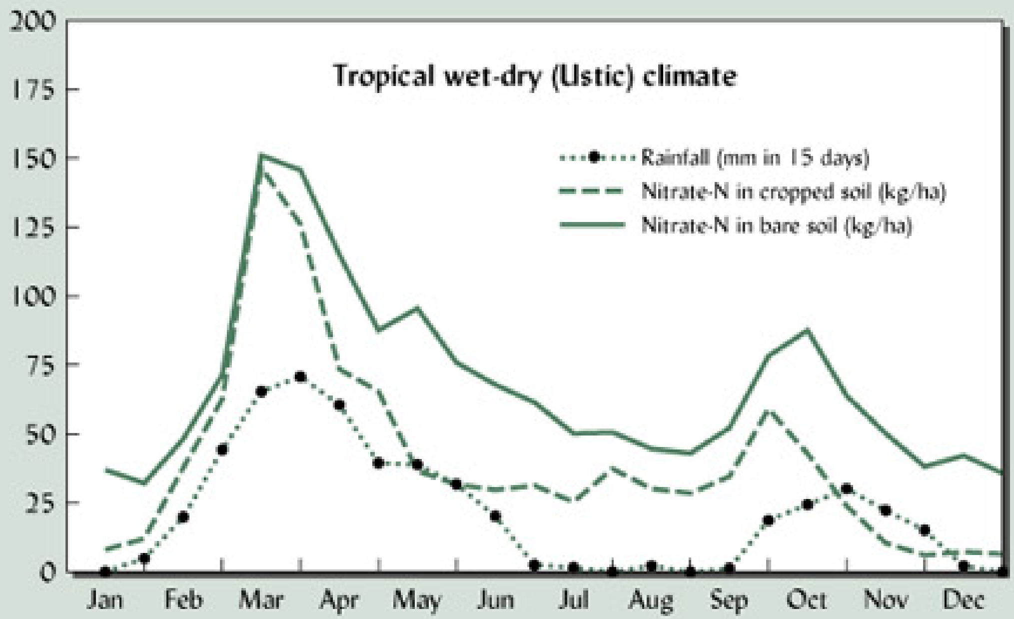




Soil drainage classes
MWD = moderately well drained
PD = poorly drained
SPD = somewhat poorly drained
VPD = very poorly drained
Measured rates of denitrification (kgN/ha/yr)
7.1
15.9
21.4
38.5
16.3
6.3
5.7
4.8
MWD
SPD
PD
VPD
VPD
PD
SPD
MWD
Developed upland
Forested upland
Unsaturated zone
Water table
Riparian zone
Riparian zone
Nitrate in ground water (mg/L)
31
10
7
Stream
<1
<1
<1
Saturated zone
0
5
10
15
20
25
30
35
40
45
50
Horizontal scale—meters

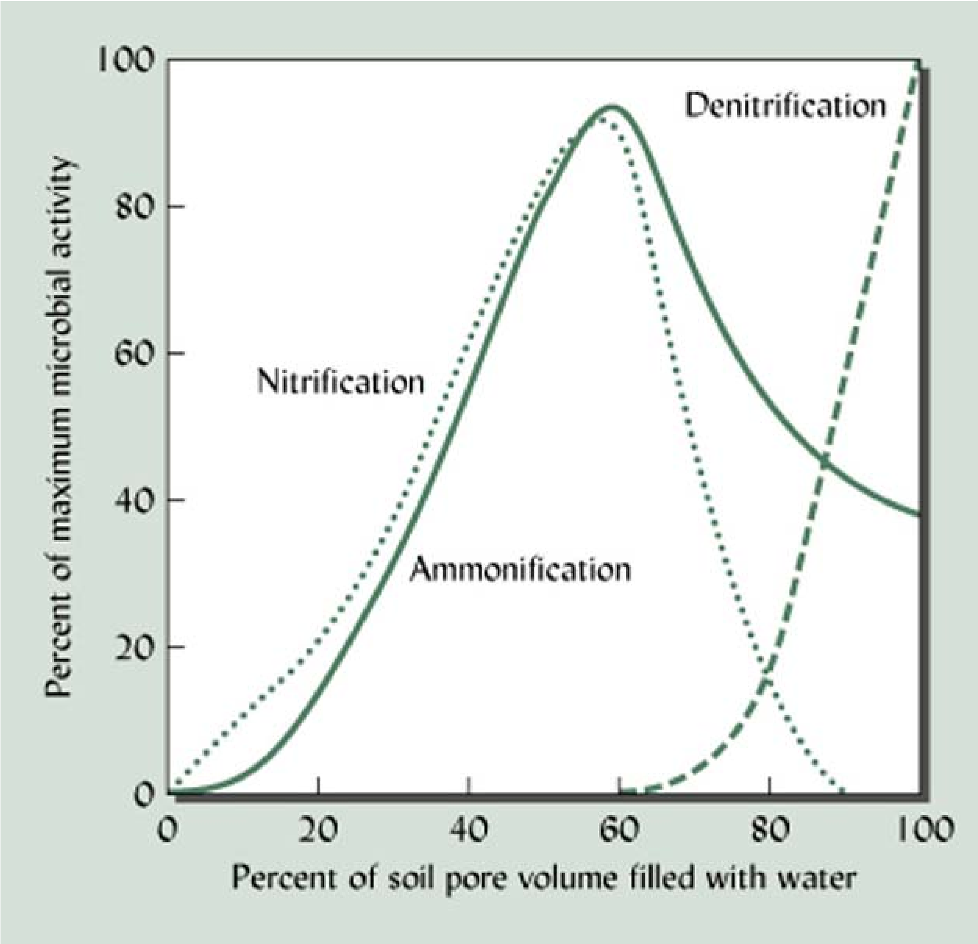

Temperate humid (Udic) climate
Rainfall (mm in 15 days)
Nitrate-N in cropped soil (kg/ha)
Nitrate-N in bare soil (kg/ha)
200
175
150
125
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

(*a*)


Tropical wet-dry (Ustic) climate
Rainfall (mm in 15 days)
Nitrate-N in cropped soil (kg/ha)
Nitrate-N in bare soil (kg/ha)
200
175
150
125
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

(*b*)

Nitrogen



Denitrification
Nitrification
Ammonification
Percent of maximum microbial activity
Percent of soil pore volume filled with water
0
20
40
60
80
100

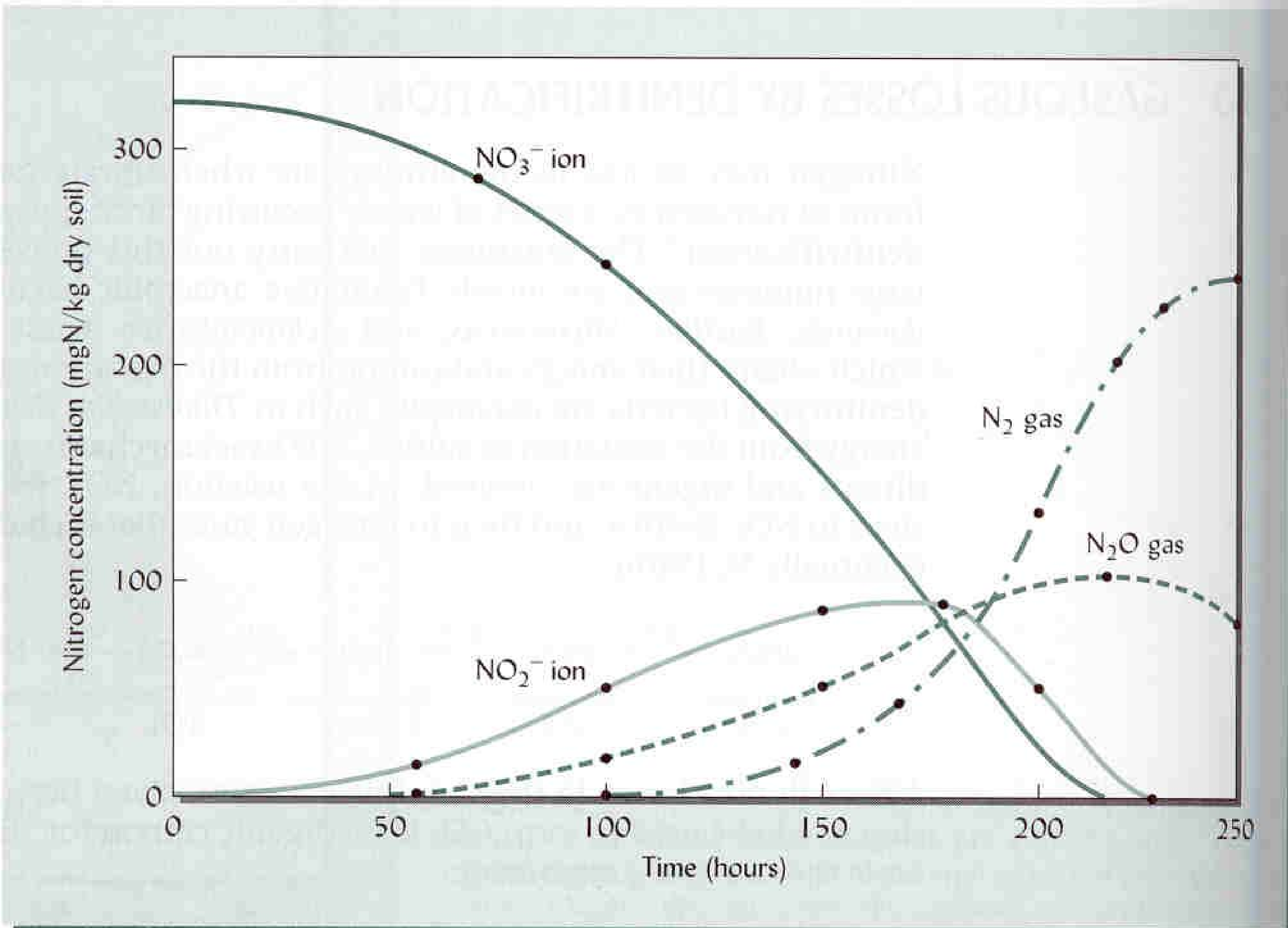
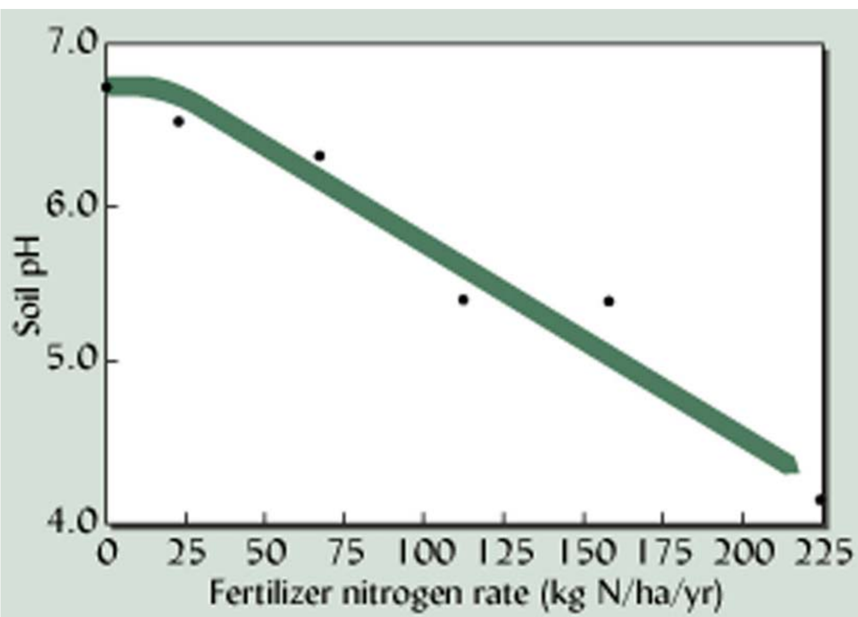
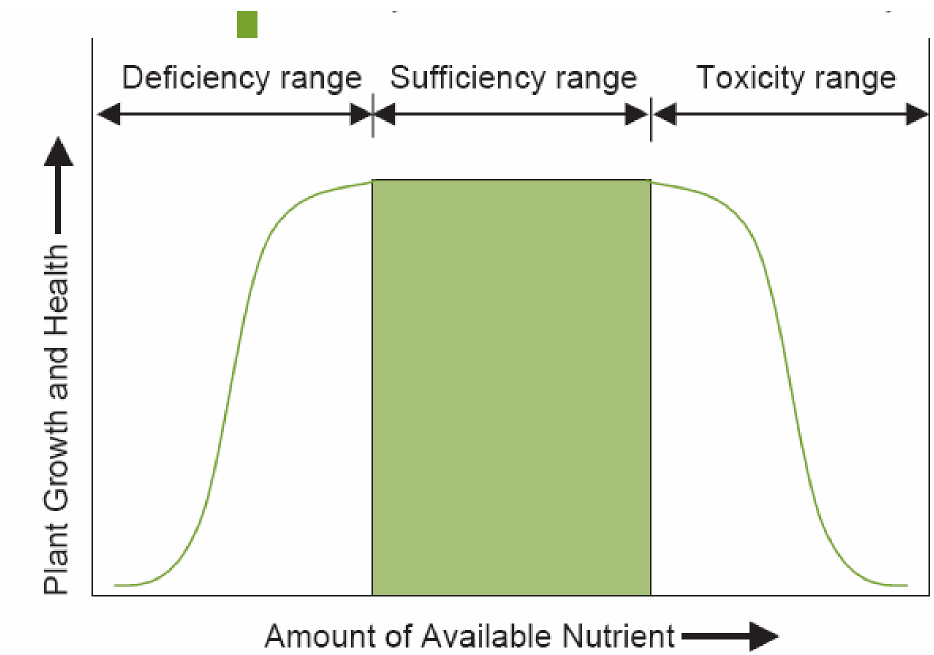


FIGURE 13.10 Changes in various forms of nitrogen during the process of denitrification in a moist soil incubated in the absence of atmospheric oxygen. [From Leffelaar and Wessel (1988)]

What are the consequences of N in the environment?

1. Plant Growth
2. Leaching – Eutrophication
3. Acidification
4. Toxicity





Ammonium toxicity chart (total ammonium ppm)

Values shown are critical total ammonium concentrations above which conditions are toxic for most fish at that pH and temperature.

pH T°C	15°	17°	19°	21°	23°	25°
7.0	7.4	6.4	5.5	4.7	4.2	3.6
7.2	5.4	4.7	4.0	3.4	3.0	2.6
7.4	3.3	2.9	2.5	2.2	1.9	1.7
7.6	2.0	1.7	1.5	1.3	1.2	1.0
7.8	1.3	1.2	1.0	0.9	0.8	0.7
8.0	0.7	0.6	0.5	0.5	0.4	0.4
8.2	0.5	0.5	0.4	0.4	0.3	0.3
8.4	0.4	0.3	0.3	0.2	0.2	0.1

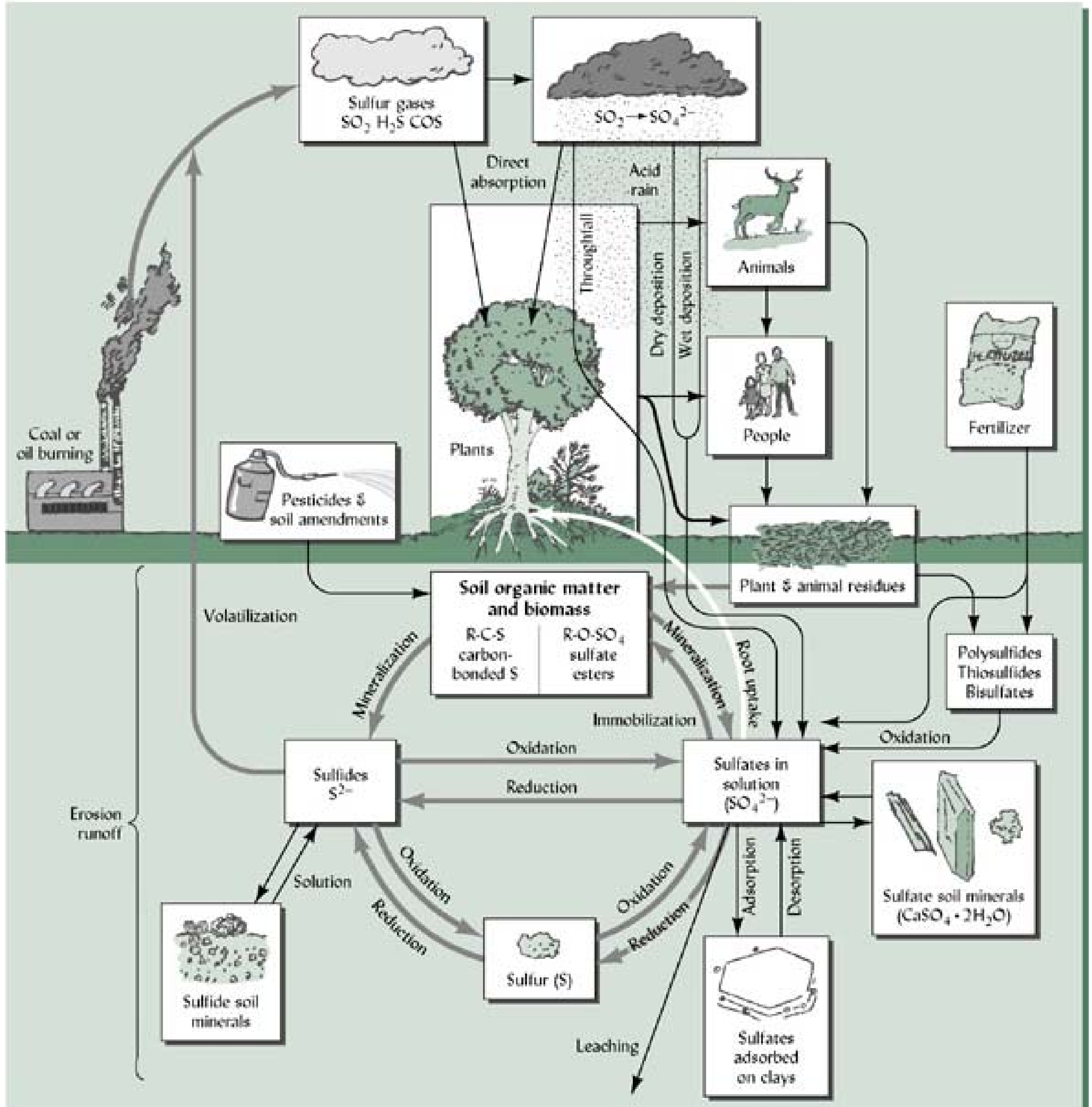
S Cycling and its behavior in Soil

Table 8.1
Major S Reserves in the Earth[a]

Reservoir	Amount of S, kg
Atmosphere	4.8×10^{9}
Lithosphere	24.3×10^{18}
Hydrosphere	
Sea	1.3×10^{18}
Fresh water	3.0×10^{12}
Marine organisms	2.4×10^{11}
Pedosphere	
Soil	2.6×10^{14}
Soil organic matter	0.1×10^{14}
Land plants	7.6×10^{11}

[a] Adapted from Freney et al.[4] and Trudinger.[6] The lithosphere refers to the crust of the earth.

Sulfur Cycle



S Sources

1. Soil Organic Matter
   @ 95 percent of the total amount of S in soils is found in SOM
   S is mineralized to SO_4. - the only form of S that is absorbed by plant.
2. Soil Minerals
   S is weathered and transformed to available SO_4
3. The Atmosphere
   Fossil fuel combustion
4. Pesticides and Fertilizers
   Some pesticides contain S - contribution of S in the soil is quite low.
   Fertilizers once supplied considerable S as impurity - Today, as the fertilizer products become more concentrated and the analysis increases, S contents are less.
5. Irrigation Water
   Where soils are sandy, the S content of the water is expected to be low.

S Losses

1. Crop Removal or Uptake

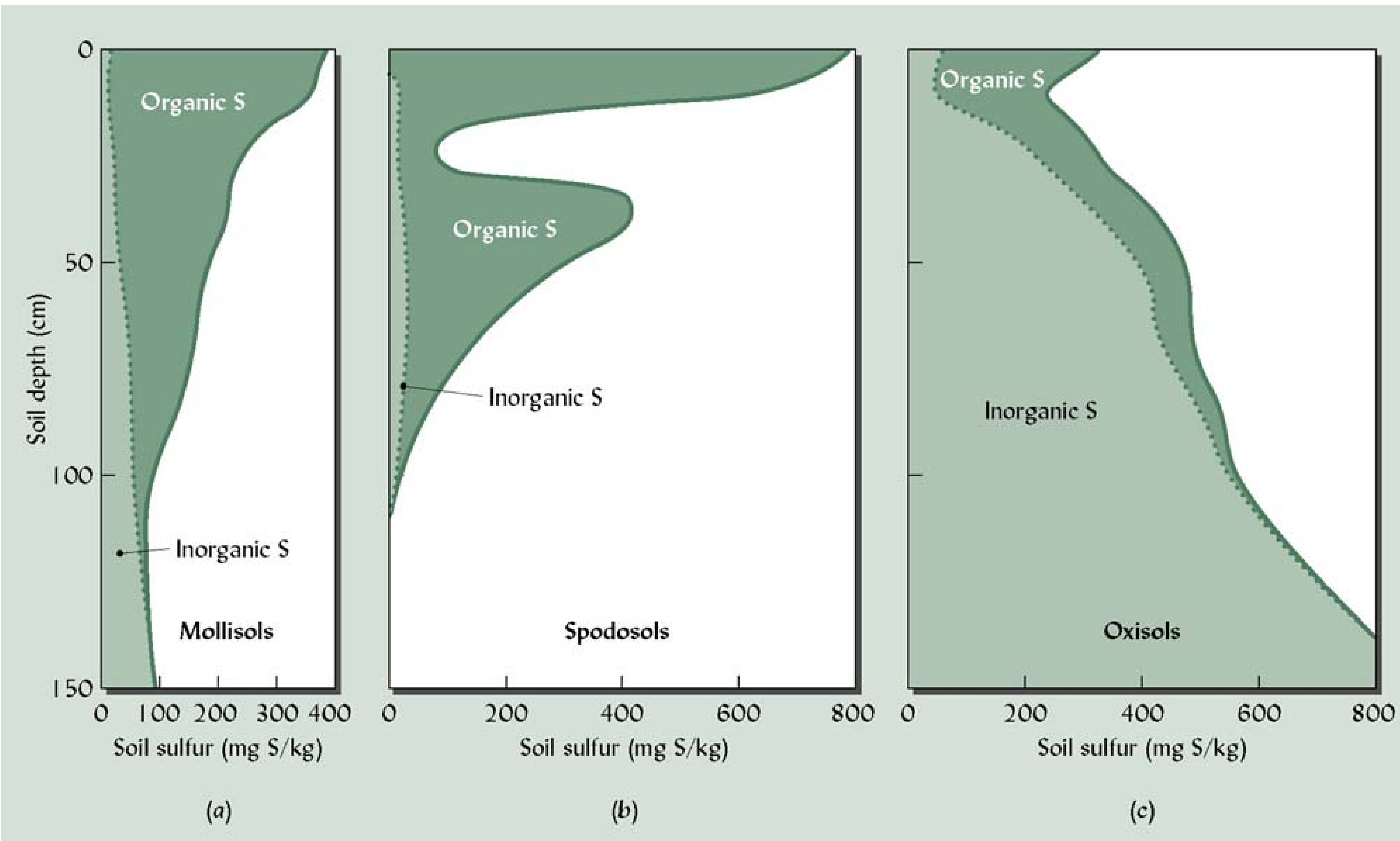
   Removal of S from the soil varies with crop and the yield of that crop

2. Leaching

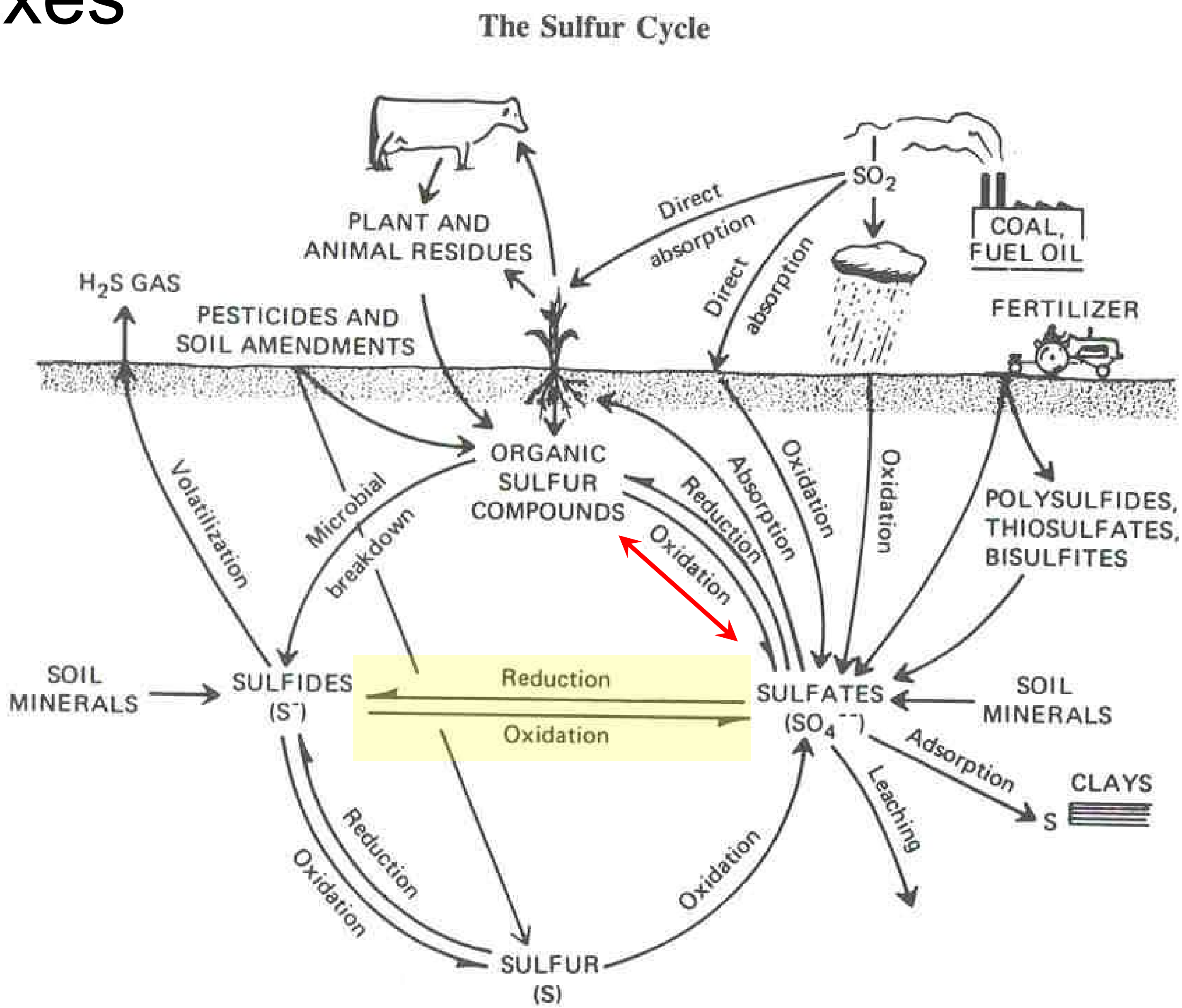
   SO_4 is soluble in water (like NO_3^-) in soils and can be moved out of the root zone by leaching. The SO_4 does not leach as rapidly as NO_3^-. But, excessive rainfall or irrigation water can move SO4-S below the root zone where soils are sandy.

S Pools

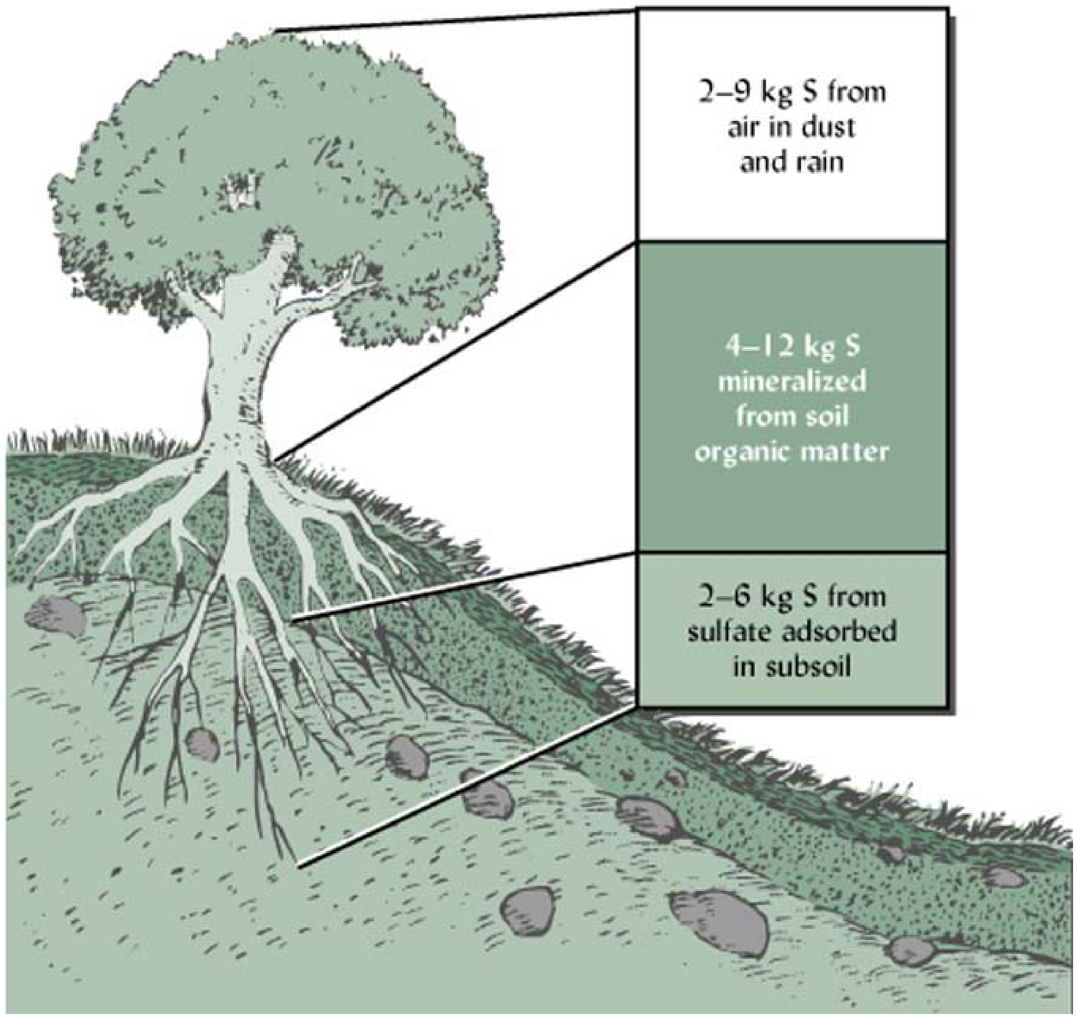
Pedosphere	
Soil	2.6×10^{14}
Soil organic matter	0.1×10^{14}
Land plants	7.6×10^{11}



Fluxes


The Sulfur Cycle
PLANT AND ANIMAL RESIDUES
SO_2
COAL, FUEL OIL
Direct absorption
Direct absorption
H_2S GAS
PESTICIDES AND SOIL AMENDMENTS
FERTILIZER
ORGANIC SULFUR COMPOUNDS
Volatilization
Microbial breakdown
Reduction
Absorption
Oxidation
Oxidation
Oxidation
POLYSULFIDES, THIOSULFATES, BISULFITES
SOIL MINERALS
SULFIDES ($S^=$)
Reduction
Oxidation
SULFATES (SO_4^{--})
SOIL MINERALS
Adsorption
CLAYS
S
Leaching
Reduction
Oxidation
Oxidation
SULFUR (S)

Plant Uptake

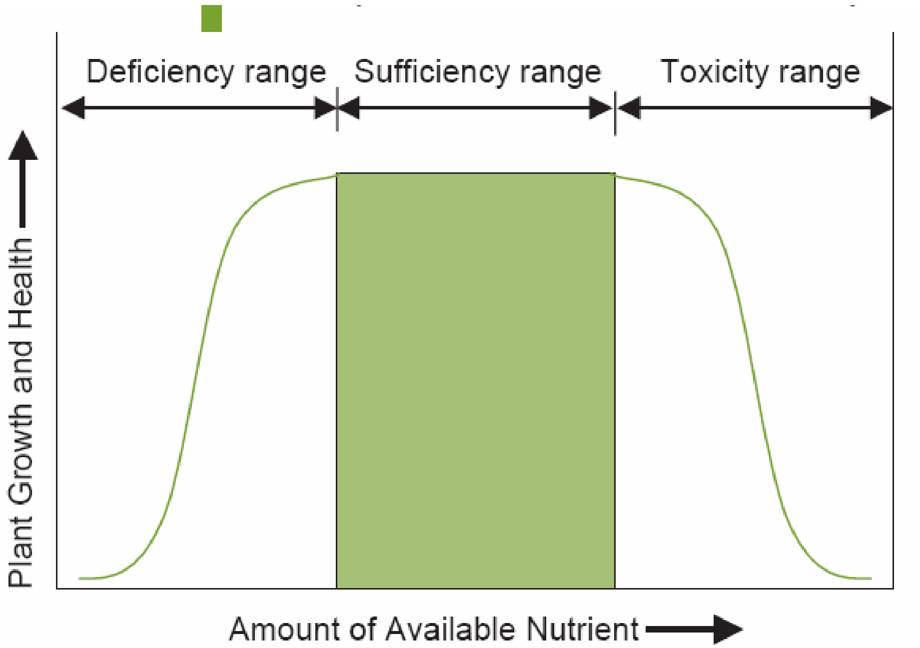


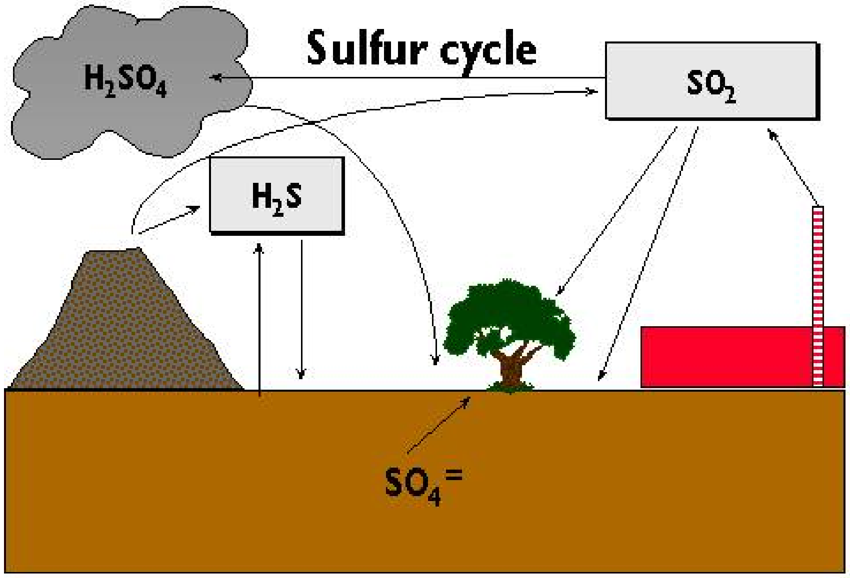
What controls these fluxes in the soil?

Temperature
Moisture
Oxygen
Sulfur

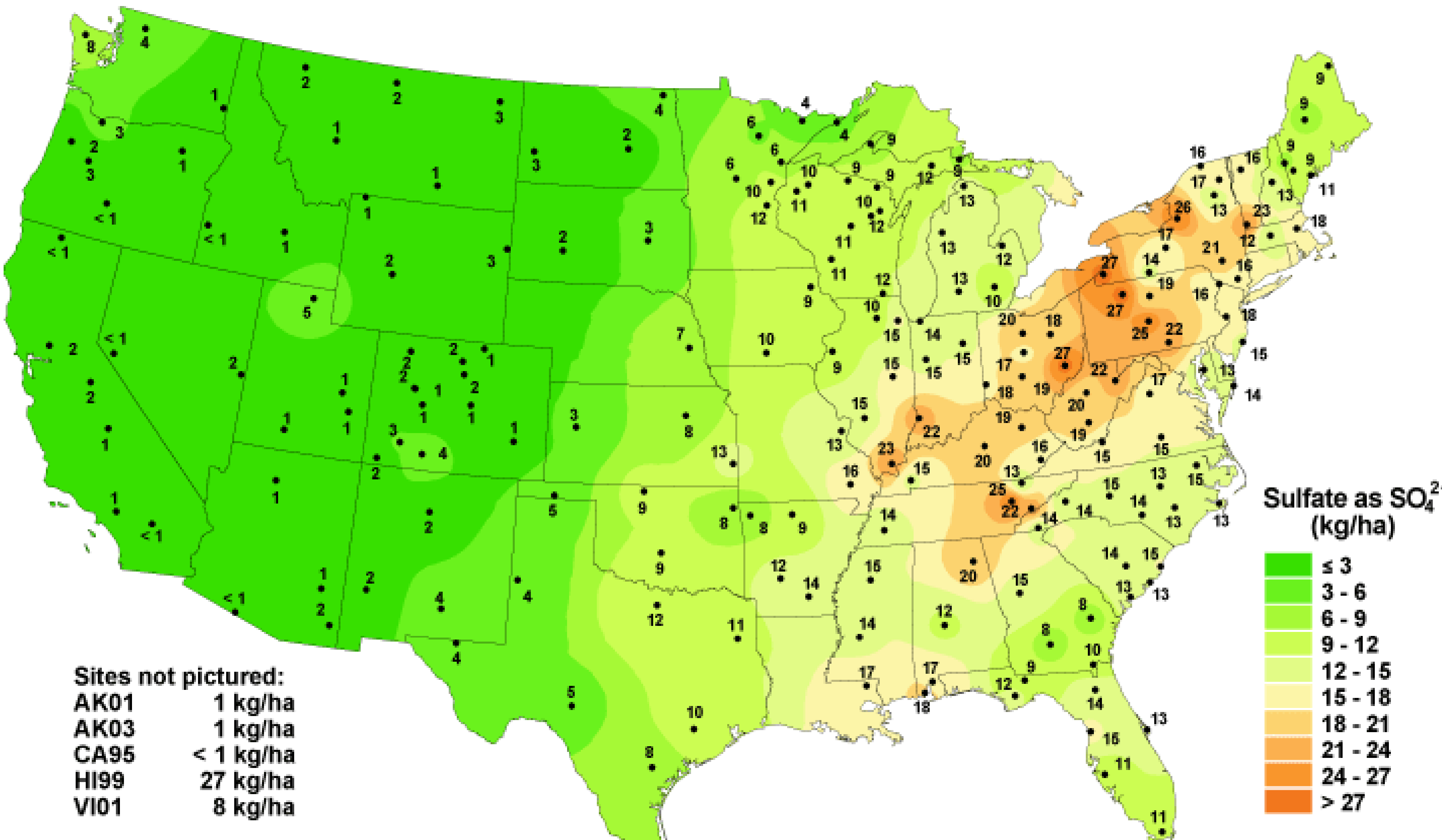
What are the consequences of S in the environment?

1. Plant Growth
2. Leaching – Eutrophication
3. Acidification
4. Toxicity

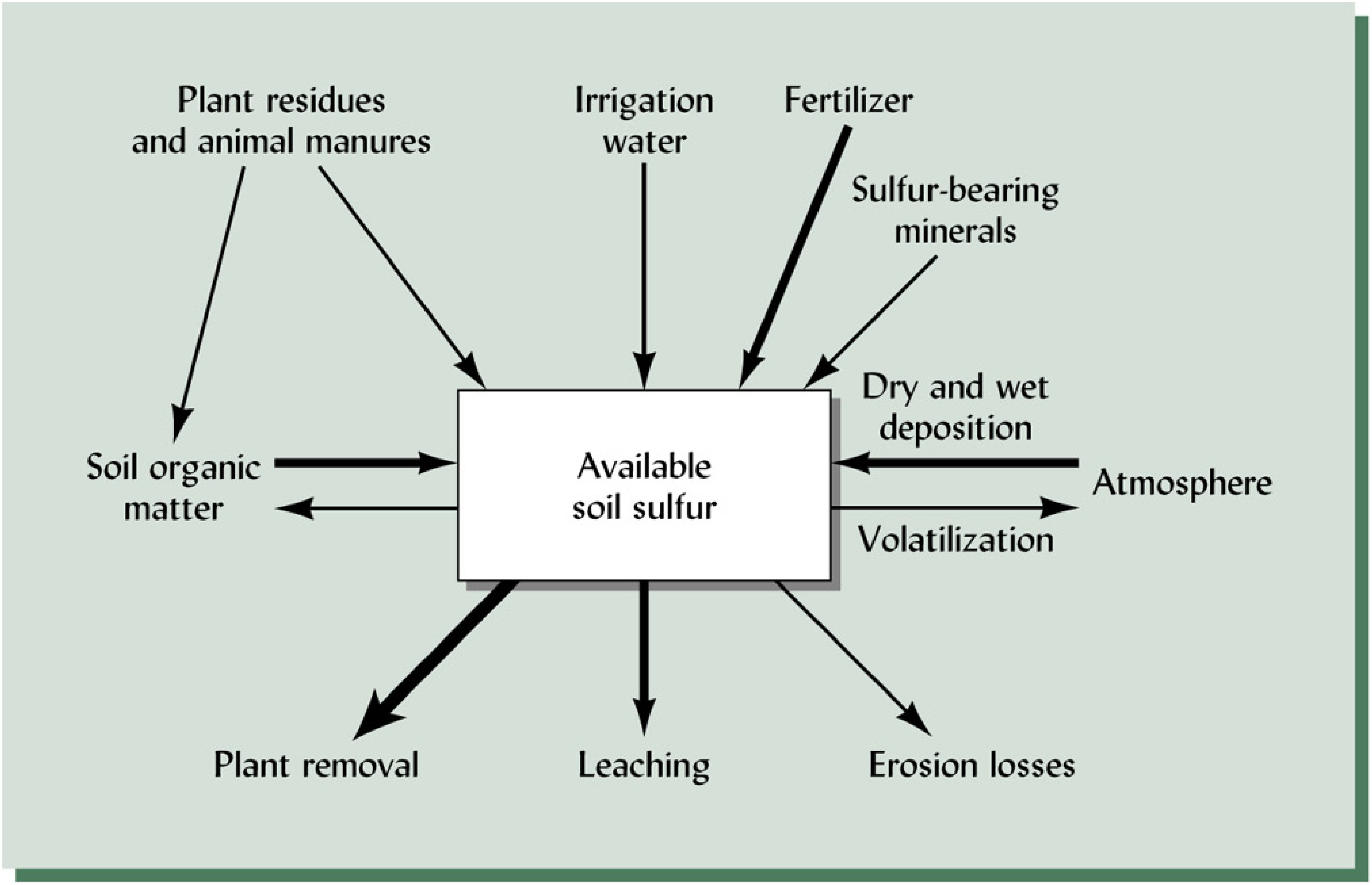




Sulfate ion wet deposition, 2002



National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu



Plant residues and animal manures
Irrigation water
Fertilizer
Sulfur-bearing minerals
Dry and wet deposition
Soil organic matter
Available soil sulfur
Atmosphere
Volatilization
Plant removal
Leaching
Erosion losses