

The Carbon, Nitrogen, and Phosphorus Cycles

Discussion Topics

Nitrogen and Phosphorus in Surface and
Ground Water

The Nitrogen Cycle

The Phosphorus Cycle

The Carbon Cycle

The Nitrogen, and Phosphorus & Carbon Cycles

➤ Relevance:

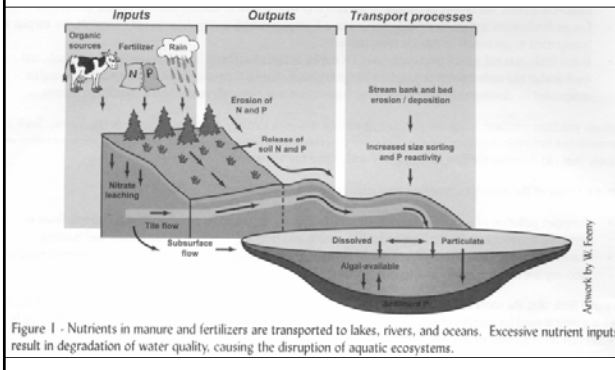
- Carbon emissions and sequestration
- Biofuels and 'New' vs 'Old' carbon
- Water and waste treatment and analysis
- Cycling and fate of C, N, and P in the environment
- Nutrient management
- etc.

Nitrogen (N) and phosphorus (P) are the two major nutrients that degrade water quality

Nutrients come from a variety of sources:

- Commercial fertilizer
- Animal manures
- Municipal sludge (biosolids)
- Municipal effluent (reclaimed water)
- Irrigation water
- Compost
- Atmospheric deposition

Nutrient Movement into Surface and Ground Water



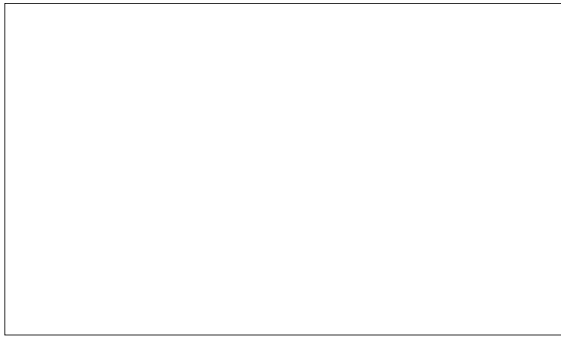
How do N and P reach lakes and streams?

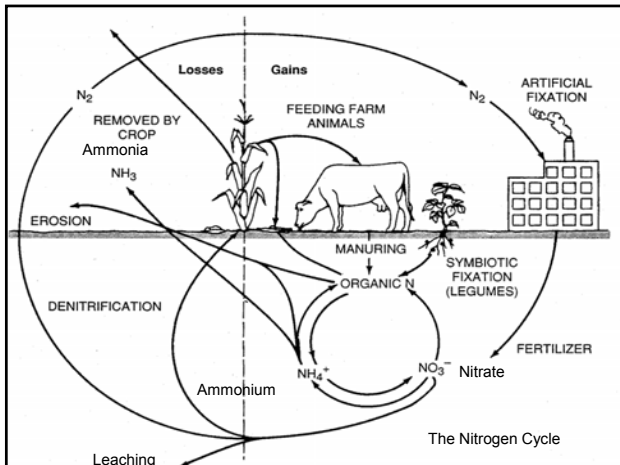
- Nitrogen can be transported to surface water through runoff, erosion, and subsurface flow
- Most, but not all phosphorus, is transported by surface runoff and erosion
 - Absorbs strongly to most soils
 - Typically retained near the ground surface
- In some soils, like the Spodosols in Florida, phosphorus can also “leach” to surface waters

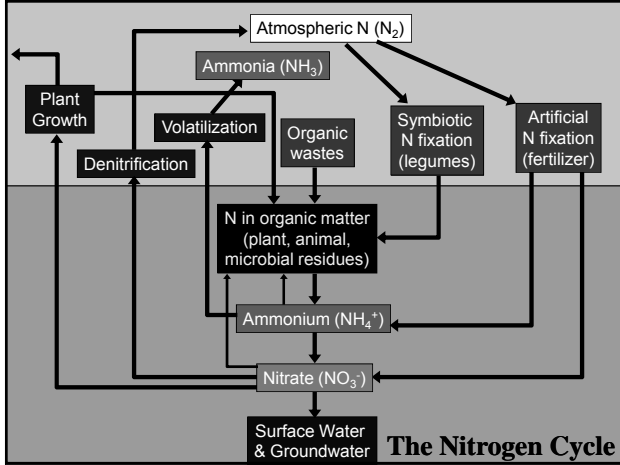
How does nitrogen reach ground water?

- Nitrogen in the form of "nitrate" is the nutrient most susceptible to leaching.
- Coarse textured soils pose the greatest problem.
- Crops with poor nitrogen use efficiency also pose a problem.
- Over irrigation, particularly on sandy soils, can cause nitrate leaching.

How does phosphorus reach ground water?







Artificial Nitrogen Fixation:
 N_2 (air) + $3H_2$ (nat. gas) \rightarrow $2 NH_3$

Symbiotic Nitrogen Fixation:
 Rhizobium + Legume \rightarrow Organic N

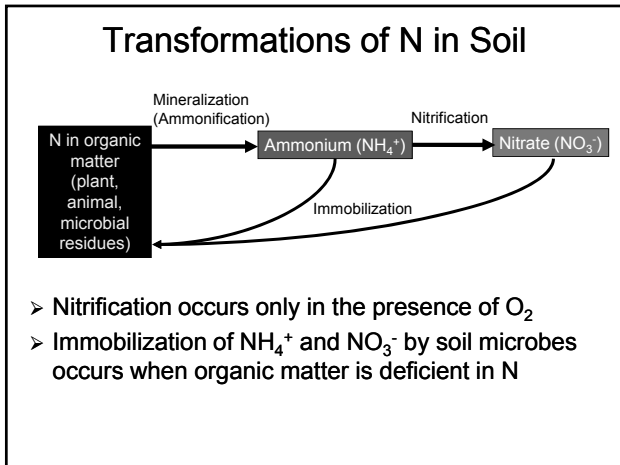
Mineralization:
 Organic N \rightarrow NH_4^+ (Ammonium)

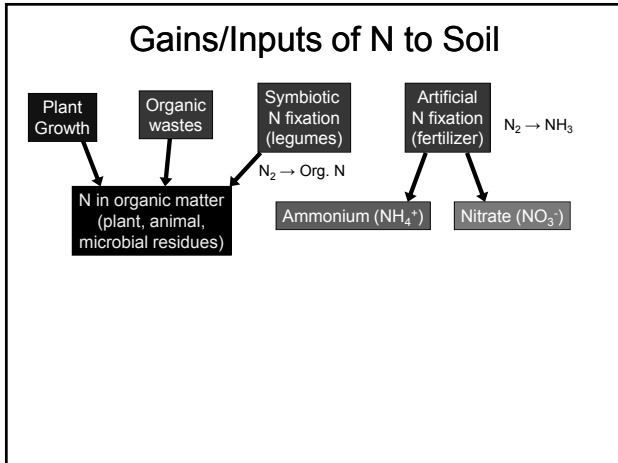
Nitrification:
 NH_4^+ \rightarrow NO_2^- (Nitrite) \rightarrow NO_3^- (Nitrate)

Immobilization:
 NH_4^+ & NO_3^- \rightarrow Organic N

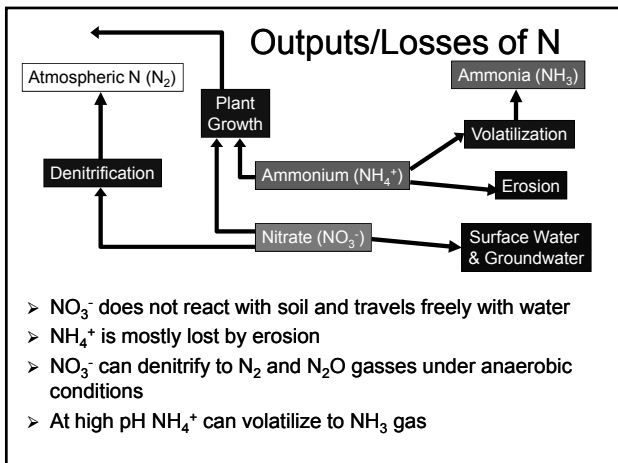
Denitrification:
 NO_3^- + lack of O_2 \rightarrow N_2O + N_2 (gases)

Volatilization: NH_4^+ \rightarrow NH_3 (gas)





- ### Haber-Bosch process
- NaNO_3 – Chile saltpeter used as source of nitrogen for more than 60% of supply
 - Fritz Haber & Karl Bosch before WWI – high temperatures and high pressures with catalysts
 - Fixes N_2 gas to create ammonia (NH_3) which can then be oxidized to create nitrate
 - First used at an industrial scale in Germany during World War I to meet the high demand for ammonium nitrate for use in explosives
 - Responsible for sustaining 40% of the world's population and consumes ~1% of the world energy production



- NO_3^- does not react with soil and travels freely with water
- NH_4^+ is mostly lost by erosion
- NO_3^- can denitrify to N_2 and N_2O gasses under anaerobic conditions
- At high pH NH_4^+ can volatilize to NH_3 gas

Nitrogen

- >95% of soil N is in soil OM.
- Nitrate dominates plant N uptake.
- Amount of OM and decomposition rate determine N availability.
- Replenishment from soil is slow.
- N is usually the most limiting nutrient for crop production.

What Happens to Nitrogen Fertilizer?

Crop uptake ----- 50%
Soil organic matter ---- 30%
Denitrified ----- 15%
Leached ----- 5-20%

Nitrogen losses from the soil

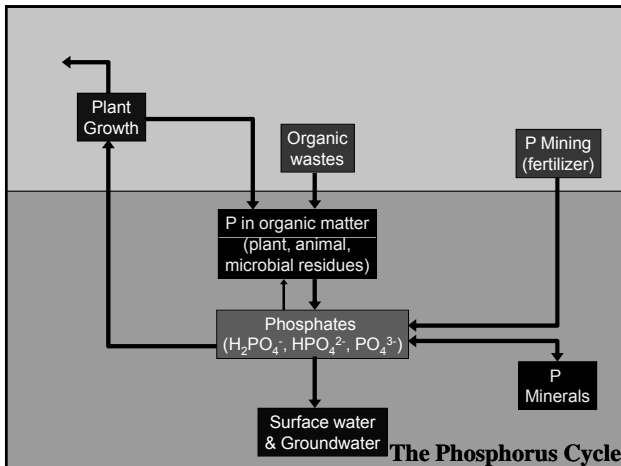
- Crop uptake
 - Some N leaves system, some returns.
- Grazing cattle
 - Some N leaves system, some returns.
- Denitrification
- Volatilization
- Leaching
- Erosion
- Runoff

Most of the N lost from soil is a result of.....

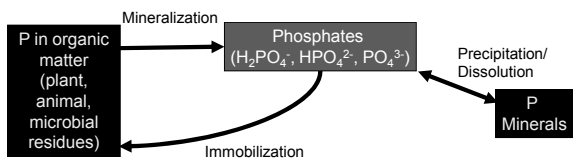
.....nitrogen "loading" of the soil (fertilizers, animal wastes).....

followed by

.....nitrogen leaching from the soil (excessive rainfall or irrigation).



Transformations of P in Soil



- Immobilization by soil microbes occurs when organic matter is deficient in P
- P minerals commonly found in soils are typically highly insoluble

Gains/Inputs of P to Soil

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    graph TD
      PG[Plant Growth] --> POM[P in organic matter  
(plant, animal, microbial residues)]
      OW[Organic wastes] --> POM
      PM[P Mining  
(fertilizer)] --> Phos[Phosphates  
(H2PO4-, HPO4 2-, PO4 3-)]
  
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- Soluble sources of P are quickly 'fixed' in most soils
- Unlike N, economically viable deposits of P minerals are a limited resource
- Florida is presently providing approximately 75 percent of the nation's supply of phosphate fertilizer and about 25 percent of the world supply. - Florida Institute of Phosphate Research
- First discovery of viable P deposits in Florida occurred outside the town of Hawthorne in 1880

Outputs/Losses of P

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    graph LR
      Phos[Phosphates  
(H2PO4-, HPO4 2-, PO4 3-)] --> E[Erosion]
      Phos --> SW[Surface Water & Groundwater]
      PG[Plant Growth] --> Out[ ]
  
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- Phosphates adsorb in **most** (but not all) soils
- Lost by erosion and surface runoff in most locations

Phosphorus

- Naturally occurs as phosphate minerals.
 - Minerals often insoluble (may not be readily available to plant)
- % of soil P in OM varies greatly depending on the abundance of phosphate minerals.
- Soils vary widely in their capacity to sorb P.

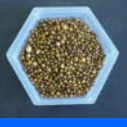
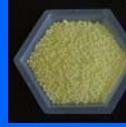
What Happens to Phosphorus Fertilizer?

- Crop Uptake
- Soil Adsorption
- Erosion
- Leaching

.....numbers vary depending on soil.....

Phosphorus losses from the soil

- Crop uptake
 - Some P leaves system, some returns.
- Grazing cattle
 - Some P leaves system, some returns.
- Erosion
- Runoff
- Leaching

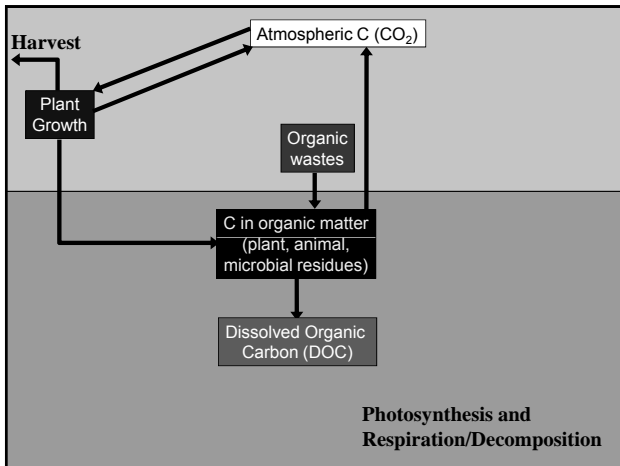
<p>Urea</p>  <ul style="list-style-type: none"> • 45% N • Soluble Synthetic Organic • Nonionic, highly leachable • Subject to volatilization • Low acidic • Low salt index 	<p>Polyon</p>  <ul style="list-style-type: none"> • 40% N • Polyurethane coated urea • N release influenced by <ul style="list-style-type: none"> - coating thickness - diffusion rate - soil temperature • good for both warm and cool season • Coating is abrasive resistant
<p>Osmocote</p>  <ul style="list-style-type: none"> • Usually a coated N P K fertilizer • N release by diffusion <ul style="list-style-type: none"> - temperature sensitive - release rates vary; 6-8, 9-10, and 11-12 months • Once coating hydrated material must remain moist or coating cracks eliminating control release properties 	<p>Sulfur Coated Urea Greens Grade</p>  <ul style="list-style-type: none"> • 32-38% N • Release depends upon <ul style="list-style-type: none"> - thickness of sulfur coating - biological - soil environment <ul style="list-style-type: none"> • temperature • pH • Cool season response-erratic • Coating fragile

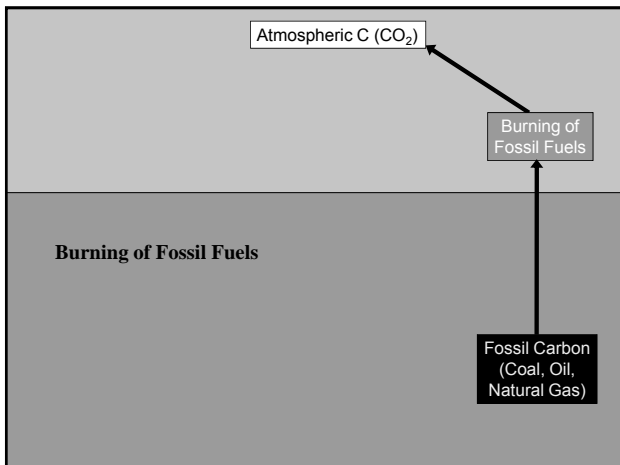
P loss from the soil results from.....

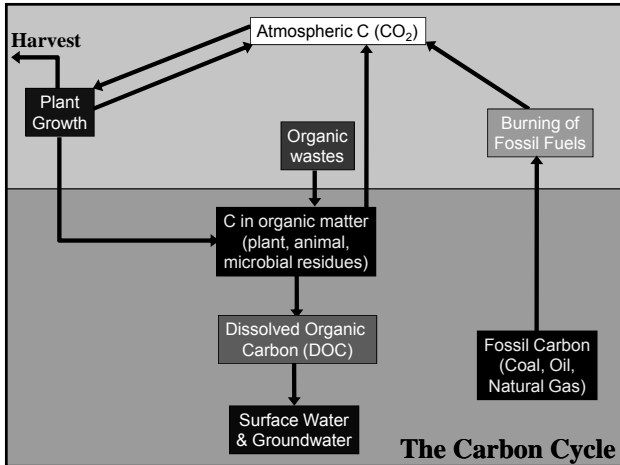
.....long-term "loading" of the soil with P from animal wastes or fertilizers.....

followed by

.....erosion of soil and organic matter particles, and/or leaching, depending on the soil.







➤ Photosynthesis:

$$\text{CO}_2 + \text{H}_2\text{O} + \text{light energy} \rightarrow \text{CH}_2\text{O} + \text{O}_2$$

➤ Respiration and Decomposition (Mineralization):

$$\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{energy}$$

➤ Burning of Fuels (in this case, methane):

$$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{energy}$$

'CO₂ Fertilization' Effect

$$\text{CO}_2 + \text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_2\text{HO} + \text{O}_2$$

➤ Photosynthesis increases in response to increases in atmospheric CO₂

➤ Most effect will be seen in plants that use the 'C3' photosynthetic pathway

- > 95% of plant species use the C3 pathway

Example Exam Questions

The conversion of ammonium to nitrate ($\text{NH}_4^+ \rightarrow \text{NO}_3^-$) is called denitrification. T ____ F ____

When ammonium (NH_4^+) is used as a source of nitrogen, there is little chance of nitrogen fertilizer loss through leaching (remember the nitrogen cycle). T ____ F ____
