Global Nutrient Cycling - Biogeochemical Cycles

Useful Conversion Factors

- $10^{12} \text{ g} = 1 \text{ teragram} = 1 \text{ Tg}$
- $10^9 \text{ g} = 1 \text{ gigaton} = 1 \text{ gt}$
- $10^6 \text{ g} = 1 \text{ metric ton} = 1 \text{ tonne}$

Mean Residence Time (MRT)

- $\text{Mean Residence Time (MRT)} = \frac{\text{pool size}}{\text{mean flux in or out of pool}}$

Fractional Turnover

- $\text{Fractional Turnover} = \frac{1}{\text{MRT}}$
- = fraction that is removed and replaced per unit time
Solar Energy Budget

Total From Sun 100%
(1.3 x 10^{21} \text{kcal per year})

- Reflected 30%
- Absorbed (heat) 47%
- Used in Evaporation 23%
- Used in Winds & Currents 0.2%
- Used in Photosynthesis 0.002%

Used to Drive the Cycles

Source of energy to most ecosystems on Earth is Solar Radiation

The Geologic Cycle
Powered by Solar & Geothermal Energy

Surface Rocks
- Weathering Erosion
- Uplifting Uncovering
- Uplifting

Metamorphic Rocks
- Critical for Driving the Cycle
- Melting

Igneous Rocks
- Weathering

Magma

Sedimentary Rocks

Soils

Critical for Driving the Cycle

GEOTHERMAL

SOLAR
The Global Water Cycle

<table>
<thead>
<tr>
<th>Pools (km³)</th>
<th>Fluxes (km³/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>33,000,000</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>13,000</td>
</tr>
<tr>
<td>Soil Waters</td>
<td>122,000</td>
</tr>
<tr>
<td>Groundwater</td>
<td>15,300,000</td>
</tr>
<tr>
<td>Oceans</td>
<td>1,350,000,000</td>
</tr>
<tr>
<td>River flow</td>
<td>385,000</td>
</tr>
<tr>
<td>Net transport to land</td>
<td>40,000</td>
</tr>
</tbody>
</table>

Reference: Schlesinger, 1997

The Global Phosphorus Cycle

<table>
<thead>
<tr>
<th>Pools (10¹² g P)</th>
<th>Fluxes (10¹² g P/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils</td>
<td>200,000</td>
</tr>
<tr>
<td>Mineable rock</td>
<td>10,000</td>
</tr>
<tr>
<td>Oceans</td>
<td>90,000</td>
</tr>
<tr>
<td>Sediments</td>
<td>4x10⁹</td>
</tr>
<tr>
<td>Fertilizers &amp; Detergents</td>
<td>12</td>
</tr>
<tr>
<td>River flow</td>
<td>21</td>
</tr>
<tr>
<td>Dust Transport</td>
<td>1.0</td>
</tr>
<tr>
<td>Land plants</td>
<td>3000</td>
</tr>
<tr>
<td>Internal cycling</td>
<td></td>
</tr>
<tr>
<td>crops</td>
<td></td>
</tr>
</tbody>
</table>

Reference: Schlesinger, 1997
Global Nitrogen Transformations

Ammonification \( \rightarrow \) Nitrogen Fixation

\[ \text{Organic - N} \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^- \rightarrow \text{N}_2 \]

- Reduced
- Oxidized
- Oxic
- Anoxic

Requires Energy

Denitrification (anaerobic respiration)

Assimilatory Nitrate Reduction releases energy

The Global Nitrogen Cycle

Fluxes \( (10^{12} \text{ g N/yr}) \)

Pools \( (10^{12} \text{ g N}) \)

- Atmosphere \( 4 \times 10^9 \)
- Oceans \( 570,000 \)
- Permanent Burial \( 10 \)
- Groundwater
- Riverflow \( 36 \)
- Denitrification \( <200 \)
- Biological Fixation \( 140 \)
- Industrial N-fixation \( 3,500 \)
- Fertilized crops \( 20 \)
- Cultivated legumes \( 40 \)
- N-fixation in lightning \(<3\)

Reference: Schlesinger, 1997
Choose two similar watersheds. Document nutrient levels in soil organic matter, plants, and streams.
Devegetate one watershed and leave the other intact. Monitor the amount of dissolved substances in streams.

**Figure 51.10a**

**Figure 51.10b**

<table>
<thead>
<tr>
<th>Year</th>
<th>Control</th>
<th>Devegetated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965–66</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1966–67</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1967–68</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1968–69</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1969–70</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The Global Carbon Cycle

- **Burning fossil fuel**
- **Atmospheric Pool**: 750
- **Measured annual increase**: +3.5
- **Ocean**: 40,000
- **Burial**: 0.1

**Pools (10^{15} g C)**
- **Land plants**: 560
- **Soils**: 1500

**Fluxes (10^{15} g C/yr)**
- **GPP**: 102
- **R**: 50
- **R**: 1.5
- **Rivers**: 1

**Year**
- **CO₂ concentration (ppm)**
  - 1960: 310
  - 1970: 320
  - 1980: 330
  - 1990: 340

**Figure 51.12b**

See Freeman, Figure 51.1
Ice Core Data Showing Changes in Atmospheric CO₂ Concentrations

Biosphere II Experiment
Why didn’t CO₂ increase?

$
\Delta O_2 \text{↓}
$

$
\Delta CO_2 \uparrow
$

\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}
\]

Respiration

“Biosphere I” Experiment

\[
\text{CO}_2 \\
\text{CH}_4 (21x \text{CO}_2) \\
\text{N}_2\text{O} (310x \text{CO}_2)
\]

Population size (billions)

CO₂ and N₂O ppmV

Population size

Time, Calendar years (A.D.)

Falkowski and Tchernov 2004