Ecosystem ecology: Concepts, data, models

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CO$_2$ increase induced stomatal closure and increased surface temperature
Nutrients and water make a difference
Liebig’s Law of the Minimum

Justus von Liebig (1803-1873)

Liebig’s Barrel

Tilman 1999 PNAS
Net carbon balance of an ecosystem
(net ecosystem production = NEP)

\[ \text{NEP} = \text{GPP} - \text{R}_{\text{auto}} - \text{R}_{\text{hetero}} \]

Where: GPP is gross photosynthesis
\( \text{R}_{\text{auto}} \) is plant respiration
\( \text{R}_{\text{hetero}} \) is the respiration of heterotrophs

- Carbon dioxide is one resource that plants need to do grow, but not the only resource!
- Nitrogen, water, phosphorus, other nutrients, temperature, physical stability, light….
- Pathogens and disease, herbivory, toxic chemicals, disturbance
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These also affect heterotrophic respiration!
Brienen et al. 2015 Nature

Figure:

(a) Net biomass change (Mg ha\(^{-1}\) yr\(^{-1}\))

Number of plots = 321
Slope = -0.034 Mg ha\(^{-1}\) yr\(^{-2}\)
P = 0.034

(b) Productivity (Mg ha\(^{-1}\) yr\(^{-1}\))

Slope = 0.03 Mg ha\(^{-1}\) yr\(^{-2}\)
P < 0.001

(c) Biomass mortality (Mg ha\(^{-1}\) yr\(^{-1}\))

Slope = 0.051 Mg ha\(^{-1}\) yr\(^{-2}\)
P = 0.001

Year: 1985 to 2010
Nitrogen
Causes of N fixation in the Environment

- Electrical Power Plants (Burning of Fossil Fuels)
- Automobiles (Burning of Fossil Fuels)
- Agriculture (Synthetic Fertilizers & Leguminous Crops)
Humans have doubled the amount of fixed N in the biosphere

Processes/Organisms that fix N:
- Lightening: <3 Tg/yr
- Free-living bacteria: ~44 Tg/yr
- Symbiotic N Fixation: ~100 Tg/yr

Human-doubling of N fixation:
- Fossil Fuel Combustion: ~20 Tg/yr
- Fertilizer production: >80 Tg/yr
- Cultivation of N fixing Row Crops: ~40 Tg/yr

1 Tg = 10^{12} g
Estimated regional and sub-regional annual nitrogen fertilizer consumption 2007 and 2012

<table>
<thead>
<tr>
<th>Regions</th>
<th>Share of world consumption (%)</th>
<th>Annual growth (%)</th>
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<tr>
<td>Oceania</td>
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</tbody>
</table>
Estimated Total Reactive Nitrogen Deposition from the Atmosphere (Wet and Dry)

Source: Galloway et al. 2004
The Nitrogen Cycle (simplified)

- **Ammonium NH₄**
  - N Fixation
  - Mineralization
  - Leaching

- **Organic Nitrogen**
  - Immobilization

- **Nitrate NO₃**
  - Denitrification
  - N₂ N₂O
  - Leaching

- **Nitrification**
Concentrations of Greenhouse Gases from 0 to 2005

- Red line: Carbon Dioxide (CO₂)
- Blue line: Methane (CH₄) x 25
- Black line: Nitrous Oxide (N₂O) x 298

Year

CO₂ (ppm), N₂O (ppb)

CH₄ (ppb)