Perspectives for the global N-cycle: Impact of future scenarios.
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Perspectives for the global N-cycle: Impact of future scenarios

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European summer school: Integrating nitrogen research 1-14 June 2008
Objectives

• To develop a future conceptual N-cycle 50 years from now
• Under consideration of the Millenium Ecosystem Report, the IPCC 4th assessment report, Nitrogen Visualisation Tool
• Starting point a present N-cycle modified after Galloway, et al., 2003
Atmosphere

Clouds  aerosols  precipitation

Fossil fuel emissions
industries transport

mineral fertilizers

Vegetation

Legumes

Animals

Bacteria

Soil

Groundwater

Freshwater

Oceans

Aquatic vegetation

eutrophication

Acid rain

Chemical reactions

Legend

F = fixation
M = mineralisation
L = Leaching
U = uptake
R = runoff
V = volatilisation
Dd = Dry deposition
Wd = Wet deposition
OD = Occult deposition
Nd = Nitrifier denitrification

Chemical reactions:

\[ \text{NH}_3 + \text{NO}_2 \rightarrow \text{NH}_4\text{NO}_2 \]

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

\[ \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \]

\[ \text{F} \rightarrow \text{M} \rightarrow \text{L} \rightarrow \text{U} \rightarrow \text{R} \rightarrow \text{V} \rightarrow \text{Dd} \rightarrow \text{Wd} \rightarrow \text{OD} \rightarrow \text{Nd} \]
Anthropogenic inputs:
- Fossil fuel consumption
- Fertiliser use
- Transport
- Animal husbandry

Atmosphere
- Chemical reactions
- Aerosols
- Lightning

Soil ecosystems
- BNF by bacteria
- BNF by legumes
- Denit. NO-N2O-N2

Water (freshwater, oceans)
- $NH_3 \leftrightarrow NH_4^+$
- $NO_2^- \rightarrow NO_3^-$
- $NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Groundwater
- $N_2$: Leaching + runoff

After Galloway et al. (2003) In 2008
4 future scenarios

Millenium Ecosystem report

- **Global Orchestration:** 2050
  Worldwide connected society, markets well developed, delayed action, problems dealt with after apparent (highest emissions)

- **Order from strength:**
  Regionalized, fragmented world, individualistic toward ecosystem management, military, national interests

- **Technogarden:**
  Globally connected world, technology, engineered ecosystems, international cooperation (lowest emissions)

- **Adapting Mosaik:**
  Fragmented world, discredited global institutions, local ecosystem management

IPCC (4th Assessment Report) 2100

- **A1:**
  Rapid economic growth, growth of population, technology, globalisation, different sub-scenarios for origin of energy

- **A2:**
  Heterogeneous world, increasing population, economic growth and technological change fragmented

- **B1:**
  Convergent world, reductions in material intensity, introduction of clean and resource-efficient technologies, global solutions

- **B2:**
  Local solutions to economic, social and environmental sustainability,
Our two future scenarios

Drivers
- Population
- Energy use
- Food
- Economy (transport)
- Agriculture efficiency
- Land use

<table>
<thead>
<tr>
<th>Neverland</th>
<th>Madmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Green and less</td>
<td>Fossil fuel and more</td>
</tr>
<tr>
<td>Less meat</td>
<td>As now (more?)</td>
</tr>
<tr>
<td>Local</td>
<td>Global</td>
</tr>
<tr>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>More nature</td>
<td>More agriculture</td>
</tr>
</tbody>
</table>

Best case
Worst case
Nitrogen visualisation

Effect of decisions relative to 2030 forecast

- Biomass use
- Intensification
- Nature area
- Meat consumption
- Transport efficiency
- Energy saving
- N-efficiency
- Renewable energy

Area:
- Food: 43.3%
- Energy: 7.5%
- Nature: 45.2%
- Urban: 4%

Emissions:

Effects:

Social:
- Prosperity index: 0.4%
- Health index: 0.7%
- Available Food: 12.9%
- Hunger: -11.2%
- Transport: -6.6%
- Energy use total: -6.8%
- Artificial Fertiliser: -13.7%
Input: size of the population, type of energy used, land use, meat consumption,…

Calculation of the emissions of $\text{NO}_x$, $\text{NH}_3$, $\text{N}_2\text{O}$, $\text{CH}_4$

Calculation of different ecological indexes: warming, acidification,…

Calculation of different socio-economical indexes: Food availability, hunger, …
Modifications of Nitrogen Visualisation:

• Nitrogen Visualisation 2030→2058

• % of change with 2007 (instead of forecasted for 2030)
Inputs: Landscape use

- Land for food
- Land for energy
- Natural area
- Urban area
Inputs: Anthropogenic factors

- Artificial Fertiliser
  - Mton fertiliser
  - 0
  - 50
  - 100
  - 150
  - 200
  - 250
  - 300

- Transport
  - Mbarrels oil required
  - 0
  - 20
  - 40
  - 60
  - 80

- Energy use total
  - Mton Oil equiv
  - 0
  - 5000
  - 10000
  - 15000
  - 20000

Legend:
- 2007
- Madmax
- Neverland
Inputs: Anthropogenic factors

Population

Biomass production

- 2007
- Madmax
- Neverland
Inputs: Anthropogenic factors

2007

Madmax

Neverland

Legend:
- Energy_renewable
- Energy_biomass
- Energy_nuclear
- Energy_fossilfuel
Anthropogenic inputs:
- Fossil fuel consumption
- Fertilizer use
- Transport
- Animal husbandry

Chemical reactions:
- Aerosols
- Lightning

Atmosphere:
- Haber-Bosch

Soil Ecosystems:
- BNF by bacteria
- BNF by legumes

Denit. NO-N₂O-N₂

N-fertilisers

BNF by bacteria

Groundwater:
- $NH_3 \leftrightarrow NH_4^+$
- $NO_2^- \rightarrow NO_3^-$

$N_r$: Leaching + runoff

Water (freshwater, oceans):
- $NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$
Anthropogenic inputs:
- Fossil fuel consumption
- Fertilizer use
- Transport
- Animal husbandry

Atmosphere
- Chemical reactions
- Aerosols
- Lightning

BNF by bacteria
$\text{NH}_3 \leftrightarrow \text{NH}_4^+$
$\text{NO}_2^- \rightarrow \text{NO}_3^-$

BNF by legumes

Denit. NO-N₂O-N₂

$\text{NH}_3$ lightning

Denit. NO-N₂O-N₂

Soil Ecosystems

Water (freshwater, oceans)
$\text{NH}_3 \leftrightarrow \text{NH}_4^+$
$\text{NO}_2^- \rightarrow \text{NO}_3^-$
$\text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$

Groundwater

$\text{N}_r$: Leaching + runoff

Neverland Scenario
Outputs and results

![Graph showing percentage of change for various environmental factors]

- NOx
- NO3
- NH3
- N2O
- CO2
- CH4
- Global Warming
- Air Quality
- Drinking Water
- Eutrophication
- Ozone Layer
- Acidification
- Biodiversity
- Prosperity Index
- Health Index
- Available Food
- Hunger

Legend:
- **Madmax**
- **Neverland**

Percentage of change:
- -100
- -50
- 0
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400
- 450
- 500
- 550
- 600
- 650
- 700
- 750
- 800
- 850
- 900
- 950
- 1000
- 1050
- 1100
- 1150
- 1200
- 1250
- 1300
Conclusions

• “Neverland” is never going to happen!!!
• “Madmax” more likely to occur.
• Quality of life would be better in “Neverland” linked with less environmental impacts.
• Drastic reduction in population would be beneficial. How?
Why reducing the population?

• Deterministic chaos:
  – System capacity
  – Big increase rate

• “Easter Island” Syndrome
  – Limited resources
  – Better technology => increasing population
  – Not enough resources => war, pest famines,…
  – (Population †)