Food for thought: Nitrogen too much of a vital resource?

Jan Willem Erisman
Louis Bolk Institute: for sustainable agriculture, nutrition and health
Outline of my presentation

• Why Nitrogen
• Sources of reactive nitrogen
• Efficiency of Nitrogen use
• Effects of Nitrogen
• Nitrogen and Diets
• Your personal Nitrogen Footprint
• What can be done to solve the N issue?
Nitrogen is necessary for life. 78% of N on Earth is N\(_2\) and unusable by organisms. To sustain human life, we convert N\(_2\) to reactive forms. The Green Revolution is largely due to synthetic N fertilizers. N\(_2\) is converted into N\(_r\) for production of fertilizer, food, feed, fibre, fuel, plastics, explosives, etc. Humans depend on internal combustion for transportation and energy. Yet, Planetary boundaries for N have been exceeded: N has direct and indirect impacts on the climate system, biodiversity loss, air and water quality, stratospheric ozone destruction, etc. Why care about nitrogen?
Anthropogenic and natural processes create reactive nitrogen

- Only a limited amount of Nr is created in nature: 99.97% resides in the atmosphere in a relatively inert form
- Ecosystems (biodiversity) are based on low availability
CREATION OF REACTIVE NITROGEN

NATURAL N\textsubscript{2} FIXATION

HUMAN N\textsubscript{2} FIXATION

NI, AS A RESULT OF POLLUTION

N\textsubscript{i} FIXATION IN AGRICULTURE

TOTAL N\textsubscript{2} FIXATION

Erisman et al. (2015)
Global trends in human population, $N_r$, $CO_2$ and grain and meat production

48% of the global population eat because of fertilizers

Erisman et al. 2008
Uneven distribution

- More than 2 billion people in the world suffer from (micro) **nutrient deficiency**, especially in developing countries. Most critical are **protein-nitrogen**, phosphorus, calcium, zinc, iron, iodine.
- An increasing number of people is **obese**.
- Probably 20% of the population ‘**eats’** 80% of the **fertilizer**.
Increase in overweight and obesity with kcal consumption and fertilizer application

Erisman et al. (2017)
Nitrogen stimulates all growth

David,
Michelangelo Buonarroti (1475 - 1564)
Nitrogen use efficiency

Energy Production: NUE = 0%

Food Production: NUE = 10 – 50%
Changes in animal production systems increasing N leakage

From a system once closely linked to local feed inputs and nutrient cycles
to one in which the production process are separated from feed production and manure application
The five key threats of excess N

Disturbance of the global N cycle is far greater in magnitude than our modification of the C cycle.
Visible impacts of terrestrial N pollution: biodiversity losses

N-poor natural ecosystems

Biodiverse woodland understorey

Lichens sensitive to air pollution

Wildflower biodiversity in meadows

N-enriched ecosystems

Loss of biodiverse understorey

Loss of sensitive lichen species

Biodiversity loss in farmed meadows
Visible impacts of coastal nutrient pollution: implications for coastal communities

- Under the microscope: Microcystis bloom, Baltic
- Noctiluca tides, New Zld. Phaeocystis foam, NL
- Caulerpa, Florida
- Green tides, Brittany
- Fish kills, Gulf of Mexico
- Shell-fishery closure

Jones, 2015
Nitrogen and the carbon cycle

N deposition increased carbon storage by:
~0.3 Pg C yr$^{-1}$ in terrestrial systems
~0.3 Pg C yr$^{-1}$ in marine areas (Blue Carbon)
Limitations of P, other nutrients ..?

Global carbon cycle, 2000-2008

Fossil fuel combustion
+7.7 Pg C yr$^{-1}$

Atmospheric growth
+4.1 Pg C yr$^{-1}$
(45%)

Ocean uptake
-2.3 Pg C yr$^{-1}$
(25%)

Land uptake
-3.0 Pg C yr$^{-1}$
(33%)

Land use
+1.4 Pg C yr$^{-1}$

Residual
+0.3 Pg C yr$^{-1}$
(3%)

Data from Le Quéré (2010)
Too much nitrogen: in a cascade

Galloway et al. 2003
The unintended costs of Nitrogen to society

- Willingness To Pay: to prevent N damage
  70-320 bln € (EU, 2000)
- Added value for the primary sector (agriculture) similar to external cost
- Global extrapolation: 200 – 2000 bln US $

40% agriculture
70% air pollution
60% human health
≈0% global warming

ENA, 2011
Economic N footprint of foods:

**Chicken Breast**
- Grocery store cost: 3 Euro
- Health/environment cost: 1.1 Euro
- Total cost = 4.1 Euro

**Steak**
- Grocery store cost: 7 Euro
- Health/environment cost: 1.9 Euro
- Total cost = 8.9 Euro

**Broccoli**
- Grocery store cost: 1.5 Euro
- Health/environment cost: 0.2 Euro
- Total cost = 1.7 Euro

**Milk**
- Grocery store cost: 1 Euro
- Health/environment cost: 0.4 Euro
- Total cost = 1.4 Euro

Economic footprint of foods: www.n-print.org
The Nitrogen Dilemma

**Benefits:**
- Necessary for life
- Nitrogen fertilizer supports food supply

**Drawbacks:**
- Excess reactive nitrogen negatively affects environmental and human health

**Challenge:**
Optimizing the use of nitrogen, while minimizing the negative impacts
Personal N footprint
A nitrogen footprint is the amount of reactive nitrogen released to the environment as a result of an entity’s resource consumption.

What major sectors are commonly included in a nitrogen footprint?

- **Food***: Food consumption and production
- **Utilities**
- **Transport**

*Food consumption and production*
Food N footprint: Definitions

**Food consumption**

= N that enters human mouth

**Virtual N**

= Food production N
= N lost to the environment during the food production process
N efficiency over the food chain

N Inputs

Farm

Supply chain

Consumers

N Losses:
Leaching, runoff, volatilization, denitrification
Food waste
Food waste

Virtual N Factor = \[ \frac{\sum N \text{ Losses}}{\text{Consumed } N} \]
The impact of FOOD CHOICES on a N footprint

1/2 cup beans 15 g protein

3 oz steak 15 g protein
Personal N footprints

Calculate your nitrogen footprint at:

www.N-Print.org
Personal N footprint in the US

N footprint (kg N/capita/year)

- Plant
- Dairy/eggs/fish
- Meat
- Housing
- Transport
- Goods & services

- Food consumption
- Energy use
Personal N footprint in the US

- Total: 39 kg N/yr
  - Food: 28 kg N/yr
    - Consumption: 5 kg N/yr
    - Production: 23 kg N/yr
  - Energy: 11 kg N/yr
What the world eats:
Personal N footprints around the world

USA
Japan
Germany
Chad
Personal N footprint by country

N footprint (kg N/capita/year)

USA

- Goods & Services
- Transport
- Housing
- Food production
- Food consumption

*Preliminary
Food makes up more than 75% of a personal nitrogen footprint

*Preliminary
Options for reducing YOUR footprint

**Energy:**
- Reduce utility usage
- Public transit
- Reduce, reuse, recycle!

**Food:**
- Recommended amount of protein
- Less animal protein
- Less N-intensive meat
- Food from sustainable farms
- Reduce food waste

Calculate your N footprint: [www.N-PRINT.org](http://www.N-PRINT.org)
Scenarios: US personal N footprint

Current N consumption: 5.3 kg N/cap/yr
Recommended N consumption: 3.0 kg N/cap/yr
Scenarios: US personal N footprint

Current N consumption: 5.3 kg N/cap/yr
Recommended N consumption: 3.0 kg N/cap/yr

- Food production
- Food consumption

N footprint (kg N/cap/yr)

Current
1) 50% food waste
2) Adv. sewage treatment
3) Vegetarian diet
4) USDA-recommended diet

-11%
-14%
-14%
-16%
Scenarios: US personal N footprint

Current N consumption: 5.3 kg N/cap/yr
Recommended N consumption: 3.0 kg N/cap/yr

N footprint (kg N/cap/yr)

Current
-11%
-14%
-14%
-16%
-43%

1) 50% food waste
2) Adv. sewage treatment
3) Vegetarian diet
4) USDA-recommended diet
5) Recommended protein

Food production
Food consumption
Scenarios: US personal N footprint

Current N consumption: 5.3 kg N/cap/yr
Recommended N consumption: 3.0 kg N/cap/yr

Food production
Food consumption

N footprint (kg N/cap/yr)

-11%
-14%
-14%
-16%
-43%
-66%

1) 50% food waste
2) Adv. sewage treatment
3) Vegetarian diet
4) USDA: recommended diet
5) Recommended protein
6) Combine #1, 2, 4, 5

Current

Current N consumption: 5.3 kg N/cap/yr
Recommended N consumption: 3.0 kg N/cap/yr
The shape of things to come

(2006 cover of The Economist)
Past and future N deposition

N deposition in 1900 in kg N / ha /yr

Lamarque et al. 2013
In order to meet the planetary boundaries system changes are needed.

Rockström et al. 2009 Nature
A resilient food system requires a system approach.

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<tr>
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<th>HIGH diversity</th>
<th>LOW diversity</th>
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<tr>
<td>Crop genetic diversity</td>
<td>Rice of different varieties</td>
<td>Rice of single variety</td>
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<td>Cropping diversity at the farm</td>
<td>Maize and beans intercrop plus agroforestry</td>
<td>Maize in monoculture</td>
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<td>Farm diversity at the region level</td>
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<td>Diversity in food</td>
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![Image showing diversity in crops and food diversity]

![Image showing the impact of climate change on agriculture]
Product N footprint (g N/kg food) for different food items in Austria

Pierer et al 2014
Thank you for your attention

j.erisman@louisbolk.nl
www.louisbolk.org