Analysis of international trade of reactive nitrogen as food and fertilizer

Shipping routes, showing number of journeys per route

Allison Leach, James Galloway, Justin Kitzes, Jan Willem Erisman, Albert Bleeker

Planet Under Pressure
Nitrogen: Too much of a good thing
26 March 2012

Kaluza et al., 2010
Overview of Talk

1. Why is N trade important?
2. Food: Trade of N embedded in food
   1. US, Netherlands, Brazil, Japan
   2. Total trade & bilateral trade of food N (2007)
3. Fertilizer: Brief overview
4. Summary
Why is the trade of N important?

• Sustains global population

• Provides foreign currency for all countries
  – Especially developing countries

• Factors to consider for N trade
  1. Amount N traded
  2. Associated Virtual N
  3. Economic cost of environmental damage
Total Food N Trade Overview

Countries: US, Netherlands, Brazil, Japan

- Trade data calculated by food category
- Includes food and animal feed
- Data source: FAOSTAT
Total Food N Trade, $Tg N$

United States

Food N Imports
Food N produced within country:
- Remaining N

Virtual N from in-country production:
- From remaining N

0.4
2

15
Total Food N Trade, $Tg\ N$

United States

Biggest exports: Cereals, Oilcrops

- **0.4**: Food N Imports into United States
- **2**: Food N Exports from United States
- **19**: Food N produced within United States
- **3**: Virtual N from in-country production

<table>
<thead>
<tr>
<th>Source</th>
<th>Exported N</th>
<th>Remaining N</th>
<th>From exported N</th>
<th>From remaining N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oilcrops</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Food N produced within country:
- Exported N
- Remaining N

Virtual N from in-country production:
- From exported N
- From remaining N
Total Food N Trade, Tg N

United States
- Pop: 301 million
- Biggest exports: Cereals, Oilcrops
- Food N produced within country:
  - Exported N: 19 Tg
  - Remaining N: 9 Tg
- Virtual N from in-country production:
  - From exported N: 2 Tg
  - From remaining N: 1 Tg

Brazil
- Pop: 190 million
- Biggest exports: Oilcrops, Cereals, Poultry
- Food N produced within country:
  - Exported N: 7 Tg
  - Remaining N: 2 Tg
- Virtual N from in-country production:
  - From exported N: 1 Tg
  - From remaining N: 0.2 Tg

Netherlands
- Pop: 17 million
- Biggest exports: Milk, Cereals, Oilcrops
- Food N produced within country:
  - Exported N: 1 Tg
  - Remaining N: 0.4 Tg
- Virtual N from in-country production:
  - From exported N: 0.2 Tg
  - From remaining N: 0 Tg

Japan
- Pop: 127 million
- Biggest exports: Fish
- Food N produced within country:
  - Exported N: 2 Tg
  - Remaining N: 0.4 Tg
- Virtual N from in-country production:
  - From exported N: 0.4 Tg
  - From remaining N: 0 Tg
Total Food N Trade, kg N
Standardized by population

Note: Scale of graphs changed

United States
Pop: 301 million

Biggest exports: Cereals, Oilcrops

Brazil
Pop: 190 million

Biggest exports: Oilcrops, Cereals, Poultry

Netherlands
Pop: 17 million

Biggest exports: Milk, Cereals, Oilcrops

Japan
Pop: 127 million

Biggest exports: Fish
**N imports to the US**

**Total Food N** \((Tg \, N)\)

<table>
<thead>
<tr>
<th>Food N Imports</th>
<th>Food N Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food N produced within country:</td>
<td></td>
</tr>
<tr>
<td>Exported N</td>
<td>Remaining N</td>
</tr>
<tr>
<td>From exported N</td>
<td>From remaining N</td>
</tr>
</tbody>
</table>

Numbers at start of arrows = Virtual N released

Final number in country = Total imported food N

Arrows show relative magnitude of imports, > 0.05 Tg N

Data include animal feed; they do not include fish/seafood
N exports from the US
Total Food N (Tg N)

Food N Imports
Food N Exports

Food N produced within country:
- Exported N
- Remaining N

In-country Virtual N:
- From exported N
- From remaining N

Numbers at start of arrows = Virtual N released
Arrows show relative magnitude of imports, > 0.05 Tg N

Final number in country = Total imported food N
Data include animal feed; they do not include fish/seafood
Imports comparison, $Tg\ N$

$N$ trade exceeding 0.05 $Tg\ N$

- **United States**
  - Imports: 0.31
  - Exports: 0.16

- **Netherlands**
  - Imports: 0.13
  - Exports: 0.23

- **Brazil**
  - Imports: 0.09
  - Exports: 0.14

- **Japan**
  - Imports: 0.12
  - Exports: 0.58
Exports comparison, \( Tg N \)

\( N \) trade exceeding 0.05 \( Tg N \)

**United States**

- **Imports**: 0.09 Tg N
- **Exports**: 0.34 Tg N

**Netherlands**

- **Imports**: 0.36 Tg N
- **N Exports**: 0.09 Tg N

**Brazil**

- **Imports**: 0.05 Tg N
- **Exports**: 0.27 Tg N

**Japan**

- **Imports**: 0.02 Tg N
- **N Exports**: 0.4 Tg N

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There are no food \( N \) exports from Japan exceeding 0.05 \( Tg N \)

However: This only represents 30% of Japan’s \( N \) exports, as the data do not include fish/seafood.
Global ammonia and urea trade
International Fertilizer Industry Association and the ICIS
<table>
<thead>
<tr>
<th>Country</th>
<th>Burden</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>Burden (food), Benefit (fertilizer)</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Burden &amp; Benefit</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Burden</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Benefit</td>
<td></td>
</tr>
</tbody>
</table>
### Cost of environmental damage from food N exports

<table>
<thead>
<tr>
<th>Virtual N from Exports</th>
<th>Cost to Repair the Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 Tg</td>
<td>€ 28 billion</td>
</tr>
<tr>
<td>1.2 Tg</td>
<td>€ 14 billion</td>
</tr>
<tr>
<td>1.6 Tg</td>
<td>€ 12 billion</td>
</tr>
<tr>
<td>0.1 Tg</td>
<td>€ 0.4 billion</td>
</tr>
</tbody>
</table>

There are no policies that address the cost of N-related environmental damage caused by the production of exported goods.
Summary

1. Significant amount of N is traded internationally as food and fertilizer

2. Environmental damage from food production is borne by the producing country

3. Current policies do not take this environmental (and economic) damage into account
Thank you!

Cattle Transport Ship: 22,000 Animal Capacity
Economic N footprint of food

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

**Chicken Breast**
- Grocery store cost: 3 Euro
- Health/environment cost: 1.1 Euro
- Total cost = 4.1 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
N imports to the Netherlands

Total Food N \( (Tg \, N) \)

Notes

*Numbers at start of arrows* = Virtual N released in a country

*Final number in country* = Total imported food N

These data include animal feed
N exports from the Netherlands
Total Food N (Tg N)

Notes

- **Numbers at start of arrows** = Virtual N released in a country
- **Final number in country** = Total imported food N
- These data include animal feed

Food N produced within country:
- Exported N
- Remaining N

Virtual N from in-country production:
- From exported N
- From remaining N

Arrows show relative magnitude of imports, > 0.05 Tg N
**N imports to Brazil:**

**Total Food N (Tg N)**

- **Food N Imports**
- **Food N Exports**

Food N produced within country:
- Exported N
- Remaining N

Virtual N from in-country production:
- From exported N
- From remaining N

**Notes**

*Numbers at start of arrows* = Virtual N released in a country

*Final number in country* = Total imported food N

Arrows show relative magnitude of imports, > 0.05 Tg N

These data include animal feed
N exports from Brazil: Total Food N (Tg N)

Notes

- **Numbers at start of arrows** = Virtual N released in a country
- **Final number in country** = Total imported food N
- Arrows show relative magnitude of imports, > 0.05 Tg N
- These data include animal feed

Food N produced within country:
- Exported N
- Remaining N

Virtual N from in-country production:
- From exported N
- From remaining N

<table>
<thead>
<tr>
<th>Food N Imports</th>
<th>Food N Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers at start of arrows = Virtual N released in a country</td>
<td></td>
</tr>
<tr>
<td>Arrows show relative magnitude of imports, &gt; 0.05 Tg N</td>
<td></td>
</tr>
<tr>
<td>Final number in country = Total imported food N</td>
<td></td>
</tr>
<tr>
<td>These data include animal feed</td>
<td></td>
</tr>
</tbody>
</table>
N imports to Japan:
Total Food N \((Tg \, N)\)

- Food N Imports
- Food N Exports

Food N produced within country:
- Exported N
- Remaining N

Virtual N from in-country production:
- From exported N
- From remaining N

Notes:
Numbers at start of arrows = Virtual N released in a country
Arrows show relative magnitude of imports, > 0.05 Tg N

Final number in country = Total imported food N
These data include animal feed
Nitrogen imports to the United States: Cereals N \((Tg \, N)\)

**Legend**
- Cereals N Imports
- Cereals N produced in US
- Virtual N from US cereals production

**Notes**
- **Numbers at start of arrows** = Virtual N released in a country
- **Final number in US** = Total imported food N
- Arrows show relative magnitude of imports, > 0.05 Tg N
- These data include animal feed
Nitrogen exports from the United States: Cereals N (Tg N)

Legend
- Cereals N Exports
- Cereals N produced in US
- Virtual N from US cereals production

Notes
- Number at start of arrows = Total Virtual N released in US
- Numbers in specific countries = Cereals N exported to a country
- Arrows show relative magnitude of imports, > 0.05 Tg N
- These data include animal feed
There are no poultry N imports to the US Exceeding 0.005 Tg N
Nitrogen exports from the United States: Poultry N (Tg N)

Legend
- Poultry N Exports
- Poultry N produced in US
- Virtual N from US poultry production

Notes
- Number at start of arrows = Total Virtual N released in US
- Numbers in specific countries = Poultry N exported to a country
- Arrows show relative magnitude of imports, > 0.005 Tg N
- These data include animal feed
<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US</strong></td>
<td><strong>Production</strong></td>
<td><strong>Imports</strong></td>
<td><strong>Exports</strong></td>
<td><strong>Supply</strong></td>
</tr>
<tr>
<td>Food weight, $Tg_{food}$</td>
<td>857</td>
<td>71</td>
<td>175</td>
<td>753</td>
</tr>
<tr>
<td>Food $N$, $Tg_{N}$</td>
<td>9</td>
<td>0.4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Virtual $N^*$, $Tg_{Virtual\ N}$</td>
<td>18</td>
<td>2</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td><strong>Production</strong></td>
<td><strong>Imports</strong></td>
<td><strong>Exports</strong></td>
<td><strong>Supply</strong></td>
</tr>
<tr>
<td>Food weight, $Tg_{food}$</td>
<td>39</td>
<td>46</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Food $N$, $Tg_{N}$</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Virtual $N^*$, $Tg_{Virtual\ N}$</td>
<td>0.9</td>
<td>1</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td><strong>Production</strong></td>
<td><strong>Imports</strong></td>
<td><strong>Exports</strong></td>
<td><strong>Supply</strong></td>
</tr>
<tr>
<td>Food weight, $Tg_{food}$</td>
<td>893</td>
<td>13</td>
<td>84</td>
<td>822</td>
</tr>
<tr>
<td>Food $N$, $Tg_{N}$</td>
<td>2</td>
<td>0.1</td>
<td>0.6</td>
<td>2</td>
</tr>
<tr>
<td>Virtual $N^*$, $Tg_{Virtual\ N}$</td>
<td>7</td>
<td>0.2</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td><strong>Production</strong></td>
<td><strong>Imports</strong></td>
<td><strong>Exports</strong></td>
<td><strong>Supply</strong></td>
</tr>
<tr>
<td>Food weight, $Tg_{food}$</td>
<td>64</td>
<td>58</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>Food $N$, $Tg_{N}$</td>
<td>0.4</td>
<td>0.9</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Virtual $N^*$, $Tg_{Virtual\ N}$</td>
<td>2</td>
<td>2</td>
<td>0.1</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Bilateral Food N Trade: Procedure

1. Started with FAOSTAT food trade matrix

2. Because food trade matrix has secondary products (e.g. bread), conversion factors were used to convert them into primary product equivalents (e.g. wheat)

3. Food trade matrix categories were mapped to the desired food product categories

4. Remaining calculations same as total food N trade calculations, as described earlier (total N, Virtual N)
Issues with bilateral food trade analysis

1. “Single step” trade analysis
   - Difficult to track products with more than one step
   - If a product is grown in country A, then shipped from B → C, trade may only be reported from B → C, depending on how countries report data

2. Secondary products
   - Data reported in secondary products (e.g. bread), whereas we need data in primary products (e.g. wheat)
   - Use factors to convert secondary products into primary products

3. Location of livestock feed
   - Feed imported into a meat-producing country becomes part of that’s country’s footprint, even though it was produced in another country

4. Virtual N from food production
   - Use the US Virtual N Factors to estimate food production N, which assumes that all countries produce food similarly to the US
Fertilizer N Trade

- Fertilizer forms: ammonia and urea
- Note: No Virtual N here
Total Fertilizer N Trade, $Tg \, N$

- **Fertilizer N Imports**: 11
- **Fertilizer N Exports**: 7
- Fertilizer N produced within country: Remaining N

**Note**: Fertilizer trade exceeding 0.3 $Tg$ fertilizer product, fertilizer production exceeding 1 $Tg$ fertilizer product

- **Biggest exports**:
  - Cereals,
  - Oilcrops

- **No fertilizer production or trade**

- **No fertilizer production or exports**

- **No fertilizer production or trade**
Nitrogen imports to the United States: Fertilizer N \((Tg \, N)\)

Legend
- Fertilizer N Imports
- Fertilizer N produced in US

Notes
- **Final number in US** = Total imported fertilizer N
- Arrows show relative magnitude of imports, \(> 0.15 \, Tg \, N\)
- Scaling of fertilizer N arrows is different than food N arrows
- Do not have Virtual N estimates for fertilizer production
Nitrogen exports from the United States: Fertilizer N ($Tg\ N$)

There are no fertilizer N exports from the US exceeding 0.15 Tg N

Legend
- Fertilizer N Imports
- Fertilizer N produced in US

Notes
Arrows show relative magnitude of imports, > 0.15 Tg N
Scaling of fertilizer N arrows is different than food N arrows
Do not have Virtual N estimates for fertilizer production
## Results: Fertilizer

### Total Fertilizer Trade for US, 2007

<table>
<thead>
<tr>
<th></th>
<th>Imports</th>
<th>Production</th>
<th>Exports</th>
<th>US Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilizer</strong></td>
<td>9</td>
<td>16</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>(Tg fertilizer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fertilizer N</strong></td>
<td>6</td>
<td>11</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>(Tg N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- Only included trade exceeding ~150,000 tonnes fertilizer N
- Fertilizer in the forms of ammonia and urea
What is Needed?

• **Awareness** in a country that action is needed to limit impacts of N losses

• **Policy** instruments in the country to limit N losses

• **International harmonization** of environmental regulations so countries are not disadvantaged in trade