ENVIRONMENTAL IMPACT – FOOTPRINTS ON THE N CYCLE

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From ignorance to knowledge

• The era of ignorance
  – Producing food without N knowledge
• Knowledge about N – I
  – Agriculture and soil biology
• Knowledge about N – II
  – Environmental implications
• Lessons learnt
  – Learning to change the future
• Future scenarios
  – We can make a difference
The history of N on Earth

Growing Food in the Era of N Ignorance

Galloway, 2016
The history of N knowledge discoveries that changed the world

1772 Daniel Rutherford
Nitrogen exists!

1836 Jean-Baptiste Boussingault
It is a nutrient!

1898 William Crookes
There is not enough of it!

1908 Fritz Haber
I can make it

1913 Carl Bosch
And I can make a lot of it!

Galloway, 2016
The history of N knowledge
And N is related to environment!!

1872 Acid Rain
1940 Biodiversity loss
1950 Coastal Hypoxia
1953 Smog
1980 N & Climate change
1985 Stratospheric Ozone loss
1989 Forest loss
2003 N Cascade

Galloway, 2016
Along the decades

1950s - Global food challenges being addressed
1970s – Awareness of water pollution and acid rain
1990s – International climate, air & water agreements
2000s – Countries fail to meet targeted commitments
2010s – Low ambition new commitments
2020s - ??????

Sutton, 2016
Reactive N is one of the three “planetary boundaries” that have been exceeded as a result of human activities.
All the WAGES environment compartments are affected

The five key threats of excess Nitrogen

The WAGES of too much nitrogen

- Water quality
- Air quality
- Greenhouse balance
- Ecosystems
- Soil quality

ENA, 2011
Nitrogen dioxide 2014 - global air quality levels (released 14 Dec 2015) (NASA satellite)
Nitrate in the oceans

Sea-surface nitrate [mmol N m\(^{-3}\)]
Application of the nitrates Directive
Excess nitrogen on landscape.

(Foley et al, 2011, Nature)
N inputs

Too Much and Too Little of Nutrients: regional variations

Estimated net anthropogenic nitrogen inputs according to the world’s main river catchments (Source: Our Nutrient World 2013).
N balance in the world
Too much nitrogen

Air pollution

Dry and wet deposition

Ozone hole

Climate change

Eutrophication
Where does excess N come from?

N used in food production

Galloway, 2016
Human created reactive nitrogen for food production Tg N/y

Increase in population; no change in per-capita protein consumption

Galloway et al., 2016
Economics for a more joined up Nitrogen Approach?

Loss as $N_r$ to air: 8 M tonne/yr
Loss as $N_r$ to water: 5 M tonne/yr
Loss as $N_2$: 9 M tonne/yr
Total N loss: 22 M tonne/yr
At €0.8/kg N = €18 billion/year
Agric. share €14 billion/year

Values for EU27 from ENA.
Component N losses to air:
NH$_3$: 3.2  NO$_x$: 3.5  N$_2$O: 1.2 (M tonne/yr)

25% of CAP
What will happen in the future?

*Increase in population but adoption of nutritional guidelines*

Galloway, 2016
Future nitrogen: should we worry?

Total fertilizer use

Sutton and Bleeker *Nature* 2013
based on FAO projections
# The Nitrogen dilemma

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Drawback</th>
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<tbody>
<tr>
<td>- Necessary for life</td>
<td>- NOx emissions</td>
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<tr>
<td>- Synthetic N fertilizer provides unlimited food supply</td>
<td>- Excess reactive N losses affect environment and human health</td>
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Galloway, 2016
The challenge

• Increasing NUE
• Minimizing losses
• Integrated efforts to address different N related threats and benefits
• Eliminate barriers to change
• Policy awareness
• Trade-offs and synergies
N flow in crop production
Nitrogen footprint

http://www.n-print.org/
http://www.pegadadoadozoto.pt/

• Food consumption N
  – Food entering human mouth
• Food production N
  – N loss into the environment during food production process
• N virtual factors
  – These factors account for each stage of the food production process (e.g., fertilizer application, processing, food waste). The losses are summed and divided by the N contained in the final consumed food product.
N calculator

Leach et al. 2012
FUTURE

• N loss reduction must be accompanied by higher yield and less inputs to obtain benefits
• Establish priorities concerning N management and research
• Funding mechanisms to support good management practices
• Include N in the Circular Economy package
• Change human behaviours (diet and consumption)