The Dutch nitrogen crisis
Historical perspective and potential solutions

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Effects of nitrogen deposition on nature: the old acid rain problem

$\text{NH}_3, \text{NO}_x (\text{SO}_2)$

$\text{NH}_4^+, \text{NO}_3 (\text{SO}_4)$

$\text{NH}_3, \text{NO}_x (\text{SO}_2)$

Decrease in diversity of plants due to:
- Eutrophication: $N$ excess
- Acidification: $\text{Ca, Mg, K}$ deficiency

De Vries et al. (2017) Nitrogen most important cause ongoing acidification
Acidification only occurs if NO$_3^-$ (by NO$_x$) or after nitrification (of NH$_3$) leaches from the soil
Details on nitrogen transformations and acid production and consumption

Acid consumption by NH$_3$ in air
\[ \text{NH}_3 + \text{H}^+ \rightleftharpoons \text{NH}_4^+ \]

Acid production by NH$_4^+$ in soil:
\[ \text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + 4\text{H}^+ + \text{H}_2\text{O} \text{ (nitrification)} \]

Acid production by NO$_2$ in air
\[ 4\text{NO}_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{NO}_3^- + 4\text{H}^+ \text{ (oxidation)} \]

Acid consumption by uptake NO$_3$ or transformation of NO$_3$ to N$_2$
\[ 5\text{CH}_2\text{O} + 4\text{NO}_3^- + 4\text{H}^+ \rightarrow 2\text{N}_2 + 5\text{CO}_2 + 4\text{H}_2\text{O} \text{ (denitrification)} \]

Acidification only occurs if NO$_3$ (by NOx) or after nitrification of nH3) leaches from the soil

Source: De Vries and Breeuwsma, 1987
Derivation of critical nitrogen loads (KDWs)

Critical N loads are derived by:

- **N addition experiments**
- Effects N deposition over time
- *Effects N deposition over gradient*
- Model calculations

![Graph showing species richness vs. total inorganic N deposition](image)

$$R^2 = 0.4023$$
Critical nitrogen loads
Kritische depositiewaarden (KDWs)

1100-1500 mol/ha/jr
700 mol/ha/jr
700-1100 mol/ha/jr
1800 - 2400 mol/ha/jr

KDW (mol of kg per ha)
- 2400 / 34
- 1857 / 26
- 1429 / 20
- 1214 / 17
- 1143 / 18
- 1071 / 15
- 857 / 12
- 786 / 11
- 714 / 10
- 571 / 8
Emission-deposition-policy since 1990

- **90’s ties:** Separate emission protocols $SO_2$, $NO_x$ and $NH_3$
- **1999:** Combined S-N-O3 Gothenburg Protocol (UN-ECE)
- **2001:** NEC directive (EU)
  - Linked to health impacts and habitat protection by N, S
  - Generic objectives; NL: 128 kton $NH_3$/260 kton $NO_x$ 2010
- **1992 Habitat Directive**
  - Habitat protection
  - Requires specific objectives per Nature area
  - Nitrogen not explicitly mentioned (external effect) but now linked to N deposition
Ammonia emissions decreased by more than 60% in 1990-2017, mainly due to **low-emission fertilization**, covering manure storage, low-emission stables, livestock reduction, protein-poor feed.

No more ammonia reduction since 2012 (release of milk quota 2015; during PAS).

NOx reduction has continued.

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**Emissie ammoniak (NH₃) door land- en tuinbouw per diercategorie**

- Kunstmest en overig
- Overig vee
- Schapen en geiten
- Puiemvee
- Varkens
- Rundvlees

**Emissie stikstofoxiden (NOₓ) per sector**

- Handel, diensten en overheid en bouw
- Consumenten
- Landbouw
- Industrie, energie en raffinaderijen
- Verkeer

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Bron: RIVM/Emissieregistratie

www.clo.nl/nloron16

Bron: Emissieregistratie

www.clo.nl/nlor8325
2019
PAS rejected by Raad van State
The Nitrogen crisis
The current N crisis

▪ Since the eighties ("acid rain"), emissions of ammonia (NH₃) and nitrogen oxides (NOx) have decreased by > 50%

▪ Nevertheless, “current” N deposition values exceed critical loads (KDWs) in 75% of the approximately 160 nature reserves

▪ Purpose of the PAS scheme: to slightly reduce deposition by giving a license based on reductions by other economic activities

▪ Permits issued on the basis of expected reductions that were not met

▪ The Council of State rejected PAS in May 29 2019

▪ Construction sector (with <1% contribution) also included in PAS

▪ Reductions needed mainly in the agricultural sector
Effects of N fertilizer on food production

- N fertilizer increases crop yields by a factor of 3-6.

- About 50% of the world's population is fed by N from fertilizers.

- It is estimated that an additional 2-3 billion people will be fed by 2050.
Nitrogen losses to air and water in the food chain

After Galloway and Cowling (2003)
Directives to reduce N use/N losses in view of related impacts

Effects on biodiversity

Bird and Habitat and NEC Directive

Ammonia (NH₃)

N output: harvested crop

Feed

Manure

Nitrous oxide (N₂O)

Climate agreement June 2019

N output: milk, meat, eggs

Effects on climate

Effects on drinking water

N input: N fertilizer N fixation N deposition

Effects on surface water

Arable land Crop production

Nitrate (NO₃)

Nitrate Directive

Nitrogen (phosphorus)

Water framework Directive
Current Dutch nitrogen policy

License for activities causing N emissions based on permissible increase in deposition on N-2000 areas using a model (AERIUS). Questionable:

- No harmonization between national emission policy (NEC directive) and provincial deposition policy (Habitat Directive)

- Uncertainties in total N deposition and extra N deposition due to an economic activity on a local scale (ha)

- N emissions cause a deposition increase over hundreds of kilometers
Bouwstenen voor nieuw stikstofbeleid

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Commission Remkes: evaluation

- Focus on integrated approach (link N use/emissions to water quality by N and P losses, GHG and PM emissions): nutrient balance accounting, avoid trade-offs.

- Balanced contribution of all sectors to reduction measures (50% reduction in both NO$_x$ and NH$_3$ in 2030).

- NO$_x$ generic (country level) and NH$_3$ region specific (provincial level): provincial nitrogen emission ceilings.

- Minimizing locally high emissions (deposition) near N-2000

- In addition, customized measures for provinces to reach KDW (contribution provinces to deposition mostly <25%).

- Policy is legally tenable (result obligation and not an effort obligation or an endeavour) and feasible (not feasible for reaching all KDW’s in 2040).
My options for a new policy versus Remkes

- Focus on reduction N surplus (reduces all N effects)
- Change from deposition policy to emission policy and determine target for emission reduction (mixed emission-deposition; all KDW’s reached 2040; not feasible, N import!)
- Divide the national emission ceiling for ammonia between the provinces (e.g. based on agricultural area).
- Do not give permission for extra activities < 1 km of N-2000.
- Focus on reducing emission ceilings in neighboring countries to reach KDWs as much as possible.
- Introduce an ammonia emission rights system (N surplus reduction is not linearly related to NH₃ emission reduction).
Generic measures

- With management measures, significant ammonia emission reductions can be achieved:
  - Less protein in feed (less N import) and more grazing
  - Separate liquid and solid manure in stable
  - Dilute fertilizer with water or acidifying fertilizer

- Note:
  - Effectiveness of measure is not always well known
  - Effect of management measures must be monitored
  - Focus is on ammonia. Think about all N losses: Danger of pollution swapping

- In total 50% reduction in 10 years hardly (not) possible without livestock reduction. Reduce feed import is partly reduce livestock
Transition to circular agriculture

- Change to circular agriculture (reduction of external N import)
  - Focus on the use of residual flows by animals (limiting imports of nitrogen and phosphate via animal feed): fewer animals
  - In addition to NH$_3$ (biodiversity), there are also NO$_3$ (groundwater), N (surface water) and N$_2$O (climate) problems

- Link to climate agreement:
  - Reduce nitrous oxide (N$_2$O) and methane (CH$_4$) emissions
  - Carbon (CO$_2$) sequestration in agricultural lands (climate smart)
  - Reduction of CO$_2$ emissions by reducing/stopping the lowering of ground water level in peat soils
Options to reduce nitrogen losses to air and water in the food chain

Production

- a. Diets
  - c. Farm mgt.
  - d. Recycle Crop Residues
  - d. Recycle Human Waste
  - d. Recycle Manure

- b. Reduce Food Waste
  - N in Food
  - N Consumed

N Fertilizer Produced

N Fertilizer Applied

N in Crop

N Harvested

N in Food

N Consumed
Thanks for the attention