Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity

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Serving society
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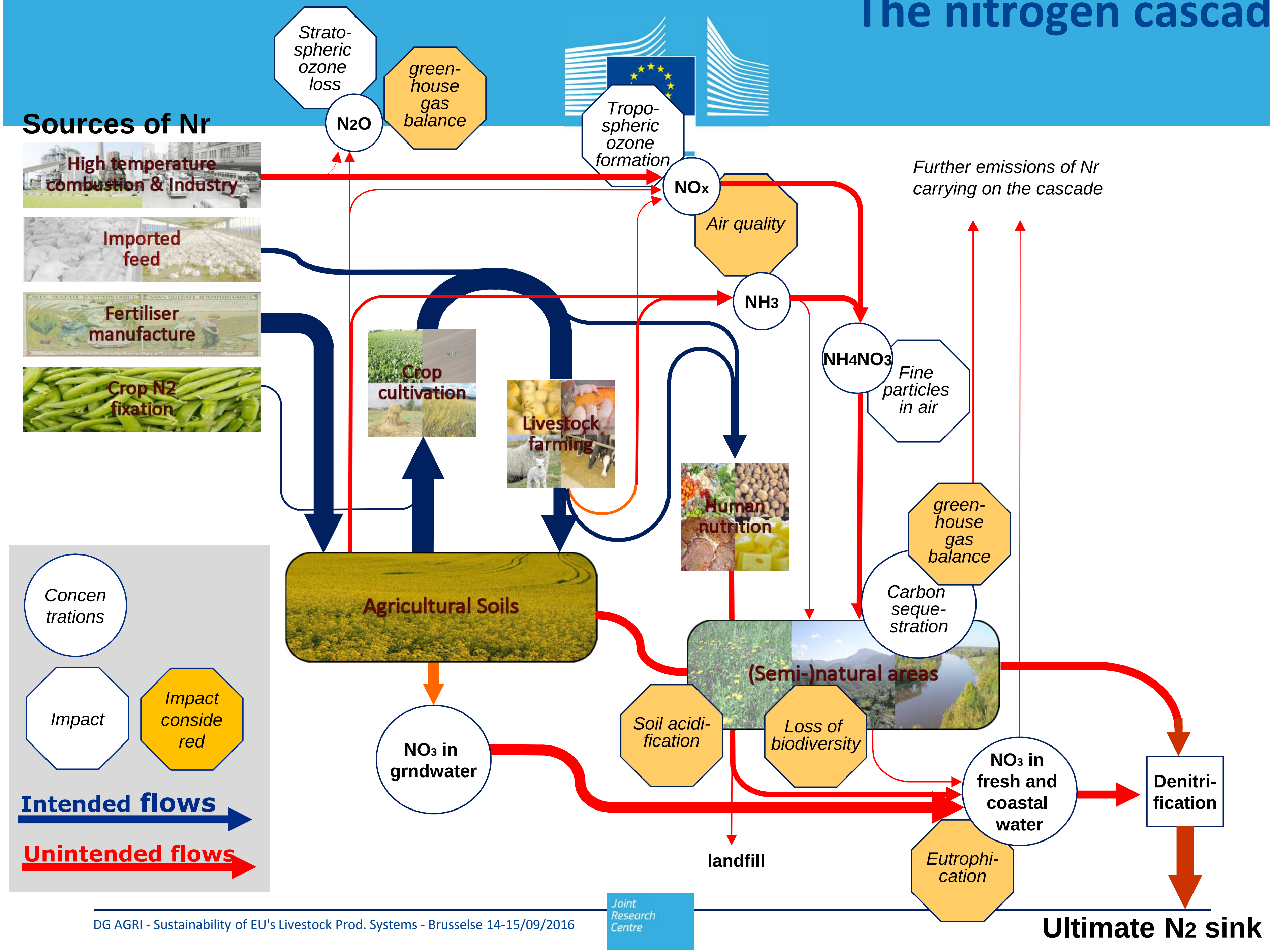
The nitrogen cascade



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The five key threats

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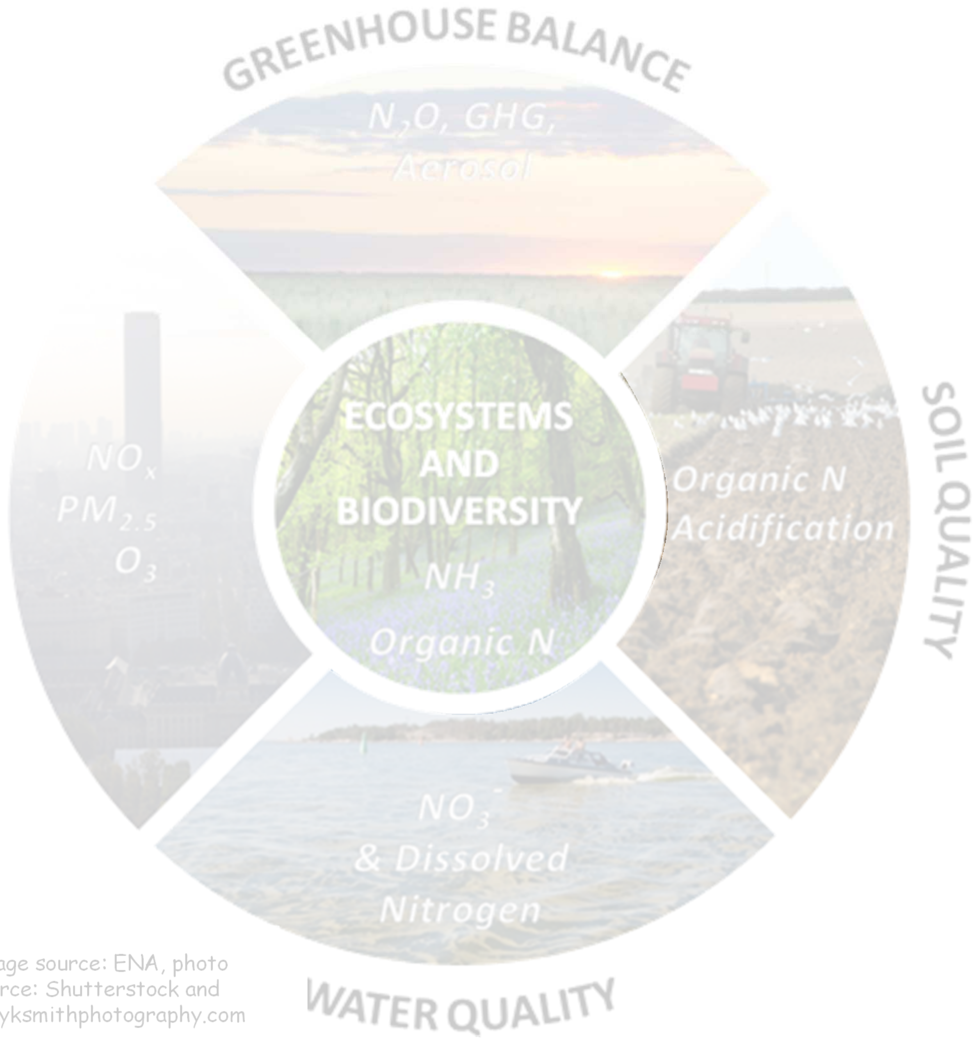

Image source: ENA, photo source: Shutterstock and garyksmithphotography.com

European Nitrogen Assessment, Sutton et al., 2011

Water quality

Coastal eutrophication, nitrate in groundwater, …

Air quality

Health effects, Cultural heritage, Crop yields, …

Greenhouse gas balance:

Carbon losses/ sequestration, N2O and CH4 emissions, indirect effects, …

Soil quality:

Erosion, soil compaction, acidification, …

Ecosystems and biodiversity:

Land use, soil eutrophication, …

Nitrogen in aquatic systems

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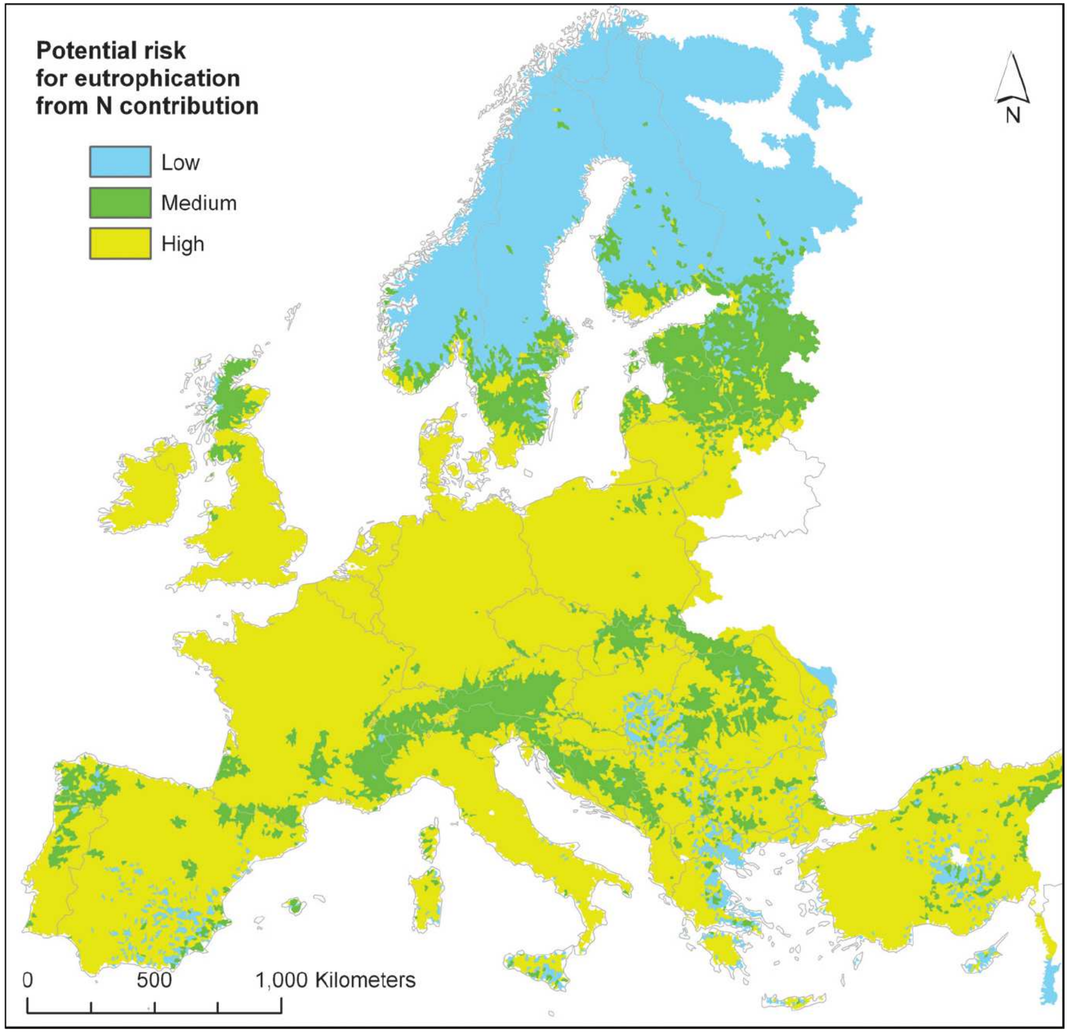
Nitrate in ground- and drinking water

Eutrophication in aquatic ecosystems

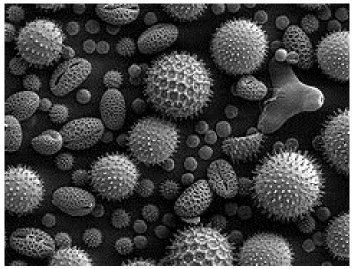


Grizzetti et al. (2011) European Nitrogen Assessment.
Brink, van Grinsven et al. (2011) European Nitrogen Assessment.

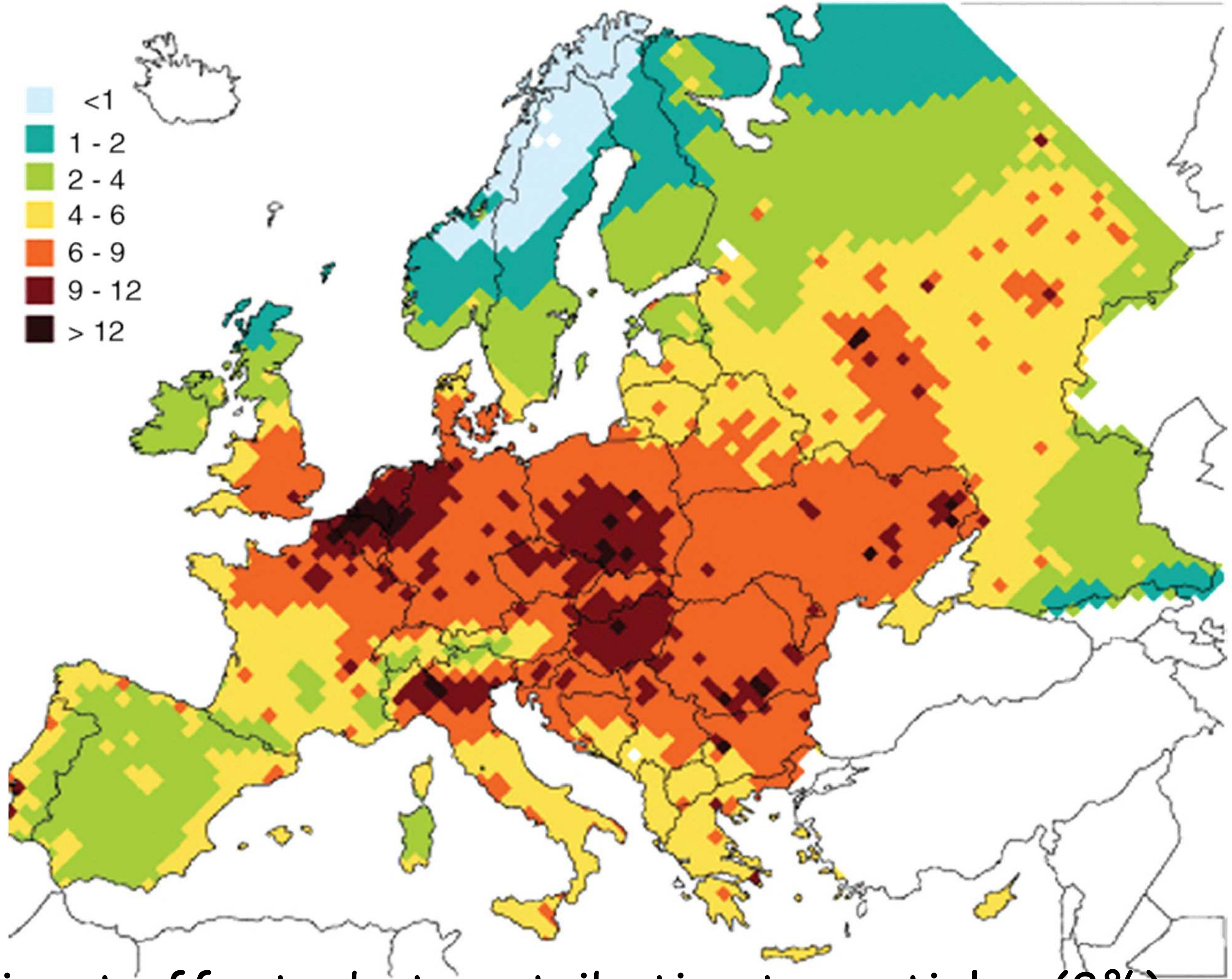
Loss in statistical human life expectancy (in months) attributable to total PM 2.5

Materials

Visibility

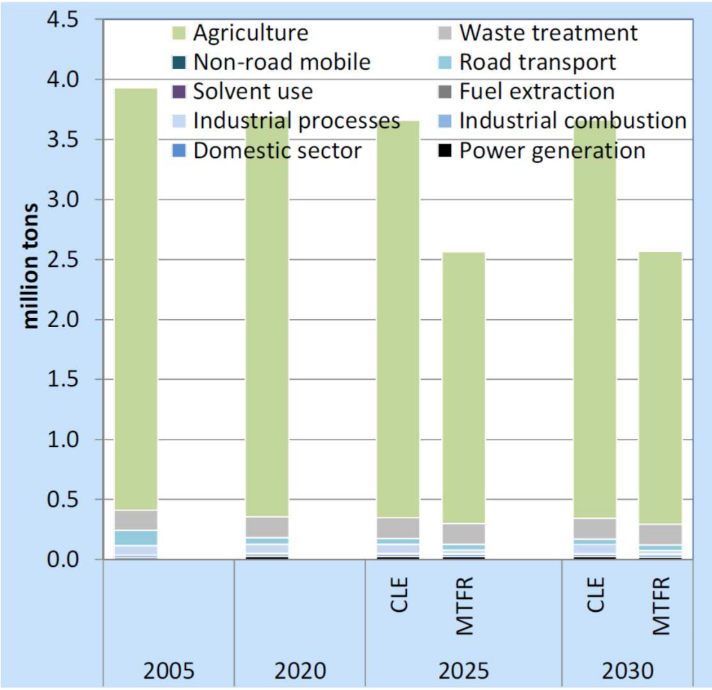


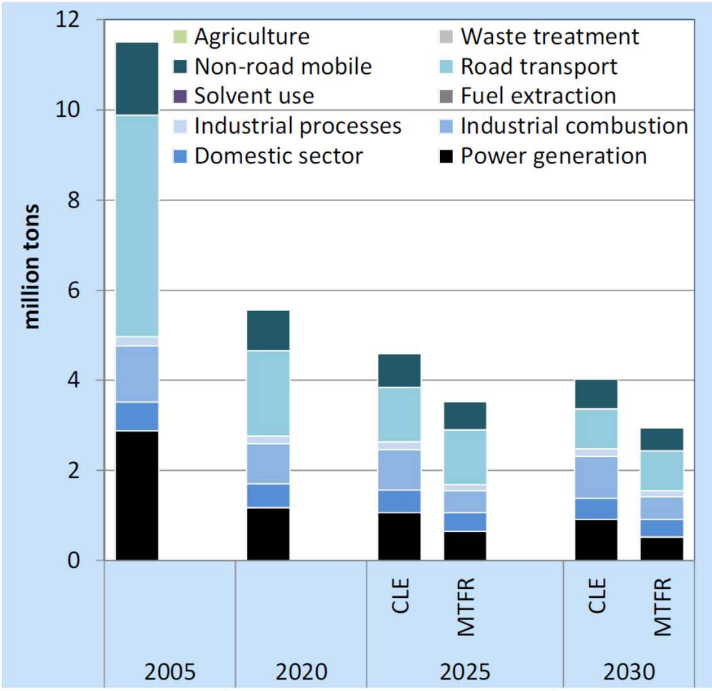
Health



NH_3: no direct effects, but contribution to particles (8%)

Moldanova et al. (2011) European Nitrogen Assessment





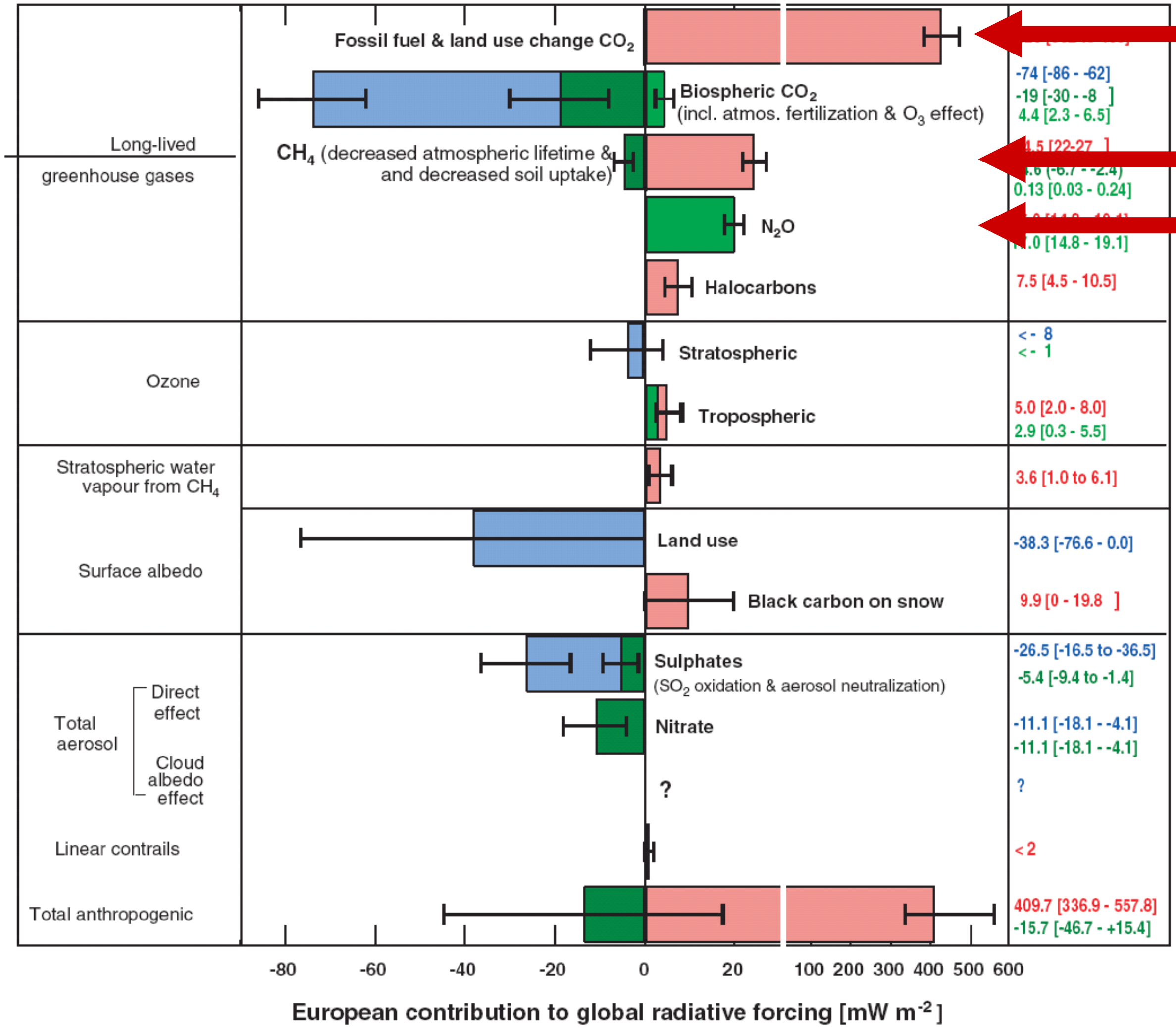
NH3 **NOx**

Amann et al., 2014. The Final Policy Scenarios of the EU Clean Air Policy Package TSAP Report #11 Version 1.1a; http://pure.iiasa.ac.at/11149/1/XO-14-076.pdf

Impact of nitrogen on radiative forcing

European Commission

Greenhouse Gas Balance



Long-lived greenhouse gases

- CH4 from enteric fermentation
- CH4 and N2O from manure management
- N2O, and CO2 from soil cultivation
- CO2 from fossil fuel
- CO2,CH4,N2O from land use change
- CO2 from land use
- C-sequestration

Butterbach-Bahl et al. (2011) European Nitrogen Assessment.

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Multiple effect of animals on biodiversity

Ecosystems and biodiversity

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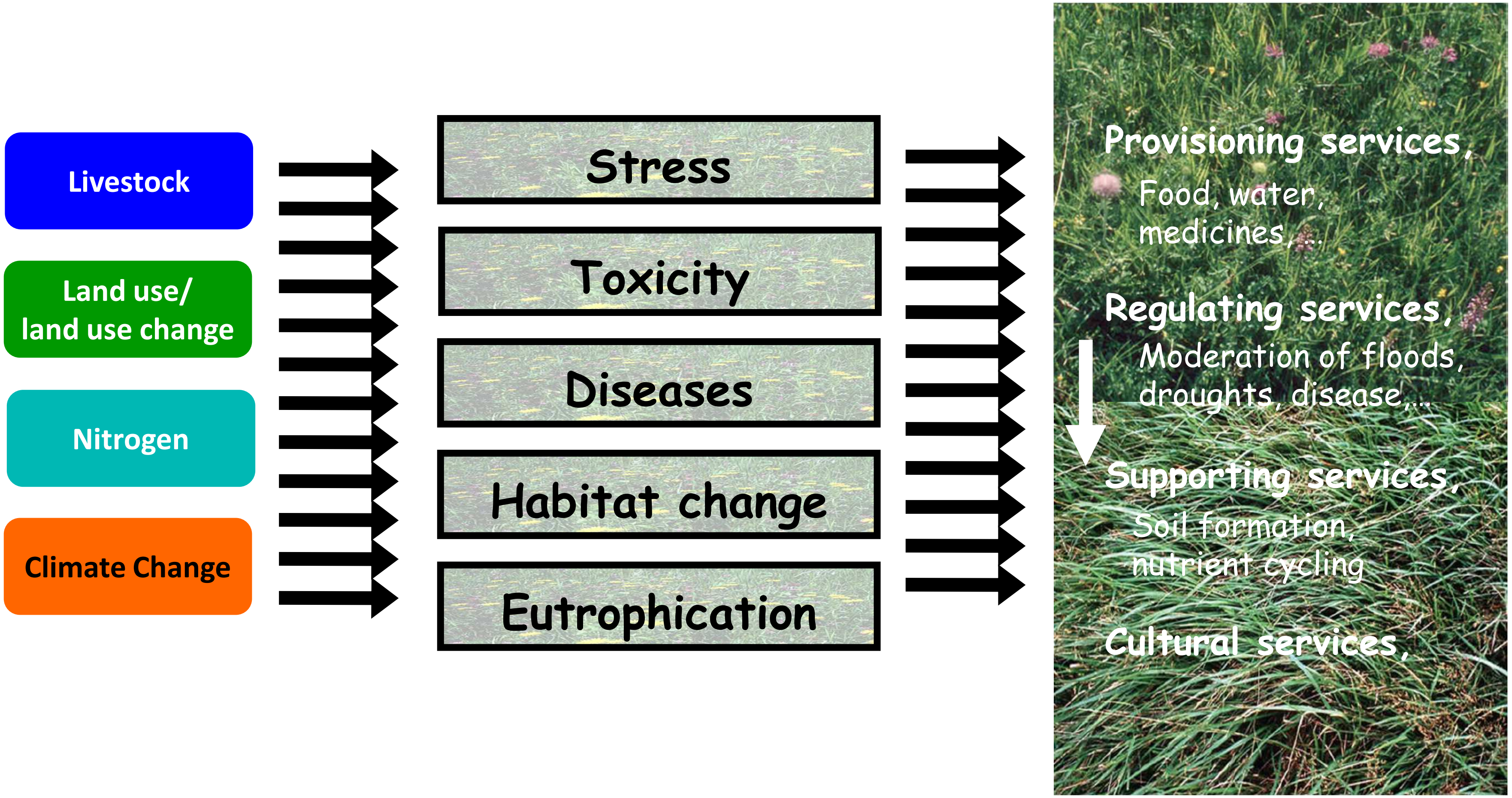
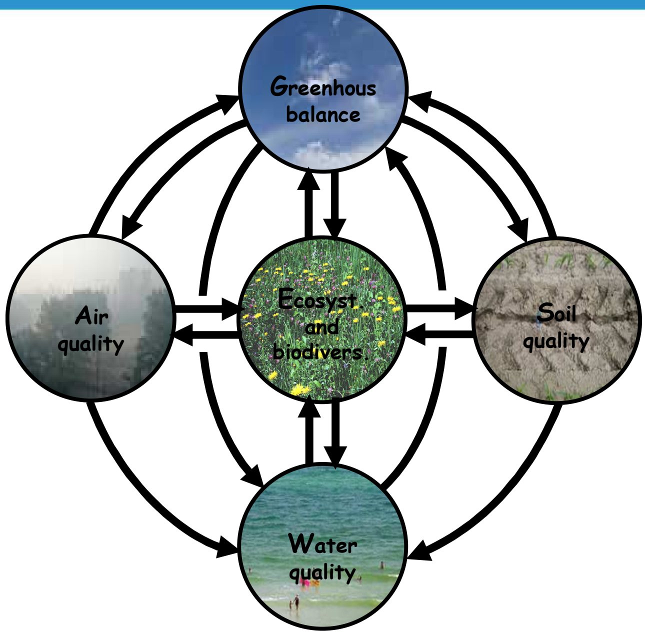
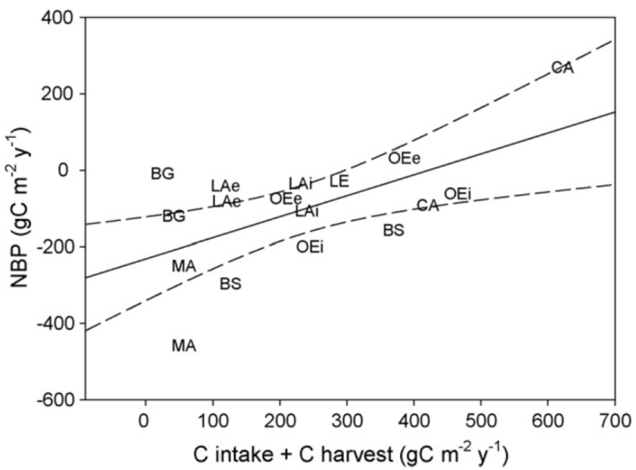


Fotos from Bobbink, 1991



- Soil organic carbon *sequestration*
  - permanent grasslands
  - forests through N-deposition (until saturation)
- "Good" soil management
  - enhances soil quality/C-sequestration
- "Bad" soil management
  - soil compaction + soil erosion
  - reduces productivity
- Peatlands lose organic matter
  - under cultivation → CO_2 and N_2O emissions
  - risk also in natural peatlands at high N-dep.
- Soil acidification
  - NH_3 is increasingly dominating
  - leaching of heavy metals



Soussana et al., AGEE, 2007

Velthof et al. (2011) European Nitrogen Assessment.

Method: using shares of relevant emissions as a proxy for contribution to impact

Table 1. Overview of emissions caused by livestock rearing and feed that were quantified in the study.

	Livestock rearing	Feed	
	Direct and energy[a]	Cultivation excl. energy[b]	Energy incl. feed processing and transport[c]
Air quality	NH_3, NO_x	NH_3, NO_x	NO_x
Climate change	CH_4, N_2O, CO_2 (NH_3, NO_x)	N_2O, CO_2 (NH_3, NO_x)	CO_2
Soil quality	NH_3, NO_x, SO_2	NH_3, NO_x	NO_x, SO_2
Terrestrial biodiversity	CH_4, N_2O, CO_2, NH_3, NO_x	N_2O, CO_2, NH_3, NO_x, land use	NO_x, CO_2
Quality of inland and coastal water	N and P losses	N and P losses	

Note: Direct livestock rearing includes livestock housing and manure management and storage; energy consumption from housing, milking, buildings etc. Cultivation of forages (grass, fodder maize, fodder beet etc) and other feed includes all direct and indirect emissions not linked with the consumption of energy.

[a] Place of emissions is EU27.

[b] Place of emissions is EU27 for forages and both EU27 and rest of the world for other feed.

[c] Place of emissions is both EU27 and rest of the world.

Models:

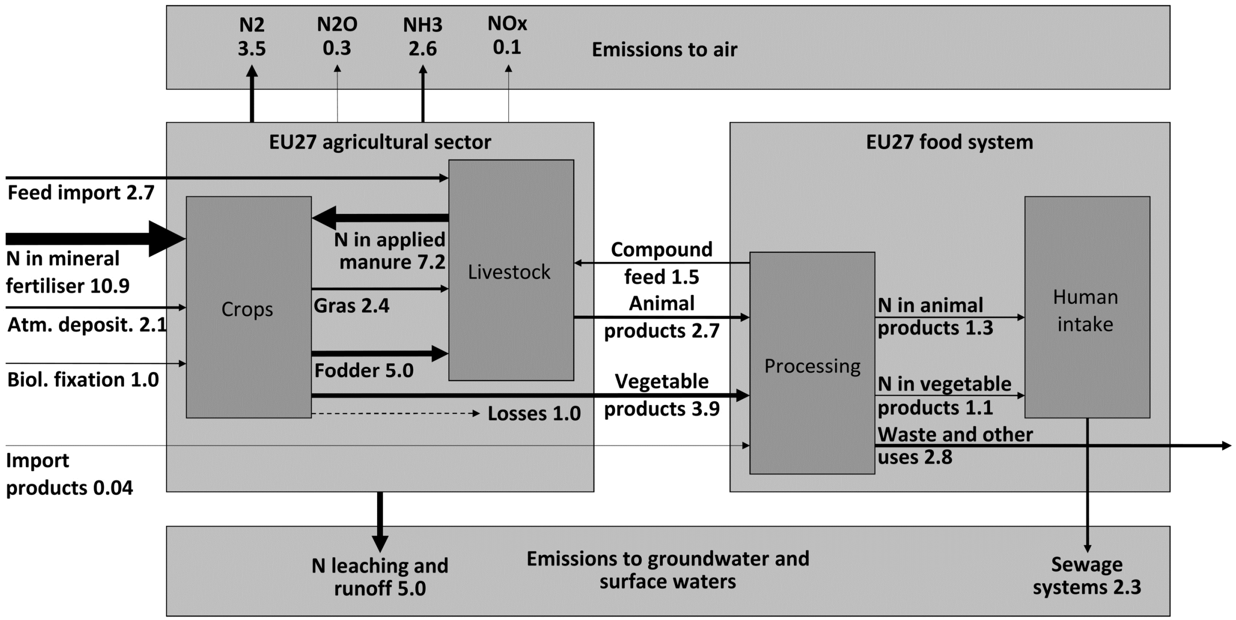
- **GHG, Nr emissions → LCA approach: CAPRI (Leip et al., 2014; Weiss and Leip, 2012)**
- **SO2: EDGAR data base (European Commission, 2011)**
- **Biodiversity: Mean Species Abundance concept: GLOBIO model (Alkemade et al., 2009)**
- **GlobalNEWS: P losses from soils to the watershed (Mayorga et al, 2010)**
- **Eutrophication potential: ICEP model (Garnier et al., 2010)**

Nitrogen Budget for Agriculture in the EU

European Commission

A nitrogen budget consists of the quantification of all major nitrogen flows across all sectors and media within given boundaries, and flows across these boundaries, in a given time frame (typically one year), as well as the changes o f nitrogen stocks within the respective sectors and media.

UNECE (2013). ***Guidance document on national nitrogen budgets.*** *Economic and Social Council Economic Commission for Europe Executive Body for the Convention on Long-range Transboundary Air Pollution. Available at: http://www.unece.org/fileadmin/DAM/env/documents/2013/air/eb/ECE_EB.AIR_119_ENG.pdf.*



Leip, A., Weiss, F., Lesschen, J.P., Westhoek, H. (2014). The nitrogen footprint of food products in the European Union. J. Agric. Sci. 152, 20–33. doi:10.1017/S0021859613000786

Joint Research Centre

Results

Table 2. Share of the livestock sector, feed production and feed imports on the emissions of pollutants due to agriculture in EU27 with relevance for air quality, global warming, soil quality, biodiversity and water quality for the year 2004.

	Air and soil quality		Air and soil quality		Air quality		Global warming	
	NH_3		NO_x		NH_3 and NO_x		GHG	
	Emissions [$Tg\,N\,yr^{-1}$]	Share	Emissions [$Tg\,N\,yr^{-1}$]	Share	Emissions [$Tg\,N\,yr^{-1}$]	Share	Emissions [$Tg\,CO_{2eq}\,yr^{-1}$]	Share
Agriculture	2.8	100%	0.46	100%	3.2	100%	1062	100%
Livestock	2.3	82%	0.30	66%	2.6	80%	861	81%
Feed	1.1	41%	0.23	49%	1.4	42%	560	53%
Feed imports	0.2	8%	0.12	25%	0.3	10%	411	39%

	Global warming		Global warming		Soil quality		Soil quality	
	C-sequestration		GHG + sequestration		SO_2		NH_3 and NO_x and SO_2	
	Emissions [$Tg\,CO_{2eq}\,yr^{-1}$]	Share	Emissions [$Tg\,CO_{2eq}\,yr^{-1}$]	Share total	Emissions [$Teq\,yr^{-1}$]	Share	Emissions [$Teq\,yr^{-1}$]	Share
Agriculture	−104	100%	958	100%	0.021	100%[a,f]	0.19	100%
Livestock	−82	80%	779	81%	0.014	67%	0.15	79%
Feed	−43	42%	516	54%	0.010	50%	0.08	42%
Feed imports	−10	10%	400	42%			0.01	8%[d]

	Biodiversity[b]		Biodiversity[b]		Water quality N		Water quality P[b]	
	Land Use		Loss of biodiversity		N		DIP[c]	
	Area [$Mio\,km^2$]	Share	Relative MSA [%]	Share	Emissions [$Tg\,N\,yr^{-1}$]	Share	Emissions [$Tg\,P\,yr^{-1}$]	Share
Agriculture	2.0	100%	−34%	100%[a,e]	6.0	100%	0.025	100%
Livestock	1.4	69%	−25%	76%	4.4	73%	0.018	73%
Feed	1.4	69%	−25%	74%	4.2	71%	0.018	73%
Feed imports	0.2	11%			0.6	10%		

Air Quality

Table 2. Share of the livestock sector, feed production and feed imports on the emissions of pollutants due to agriculture in EU27 with relevance for air quality, global warming, soil quality, biodiversity and water quality for the year 2004.

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Global warming

Air Quality

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Soil quality

Global Warming

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	Global warming					
	GHG		C-sequestration		GHG + sequestration	
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Livestock	861	81%	−82	80%	779	81%
Feed	560	53%	−43	42%	516	54%
Feed imports	411	39%	−10	10%	400	42%

ca 1/3 Land use change and energy
ca 1/3 Livestock emissions
ca 1/3 Soil emissions

Soil Quality

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	Soil quality			
	SO_2		NH_3 and NO_x and SO_2	
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Agriculture	0.021	100%[a,f]	0.19	100%
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Biodiversity

Table 2. Share of the livestock sector, feed production and feed imports on the emissions of pollutants due to agriculture in EU27 with relevance for air quality, global warming, soil quality, biodiversity and water quality for the year 2004.

Table S3-1 Drivers of biodiversity loss in the EU-27 in 2010, and share of livestock production in this loss.

$ Infrastructure, encroachment and fragmentation

	Unit	Driver of biodiversity loss: Conversion of land to: Crop land	Grazed land	Forest land	N deposition	Climate Change	Land use$	Total biodiversity loss
Results from the GLOBIO model (Alkemade et al 2009, Kram and Stehfest 2012)								
MSA loss due to	% of original biodiversity	23	10	9	2	2	20	65
MSA loss due to	% of biodiversity loss	35	15	14	2	3	30	100
Results from this study								
Share of all agriculture in pressure factor	% of original biodiversity	23	9.6	0	0.9	0.3	0	34
	share in driver of biodiversity loss relative	100	100	0	57	12	0	
Share of livestock in pressure factor	% of original biodiversity	15	9.6	0	0.7	0.2	0	25
	share in driver of biodiversity loss relative	65	100	0	44	8	0	
Share of feed in pressure factor	% of original biodiversity	15	9.6	0	0.3	0.1	0	25
	share in driver of biodiversity loss relative	65	100	0	21	2	0	

	Biodiversity[b] Land Use: Area [Mio km²]	Share	Biodiversity[b] Loss of biodiversity: Relative MSA [%]	Share
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Water Quality

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	odiversity	N		DIP[c]	
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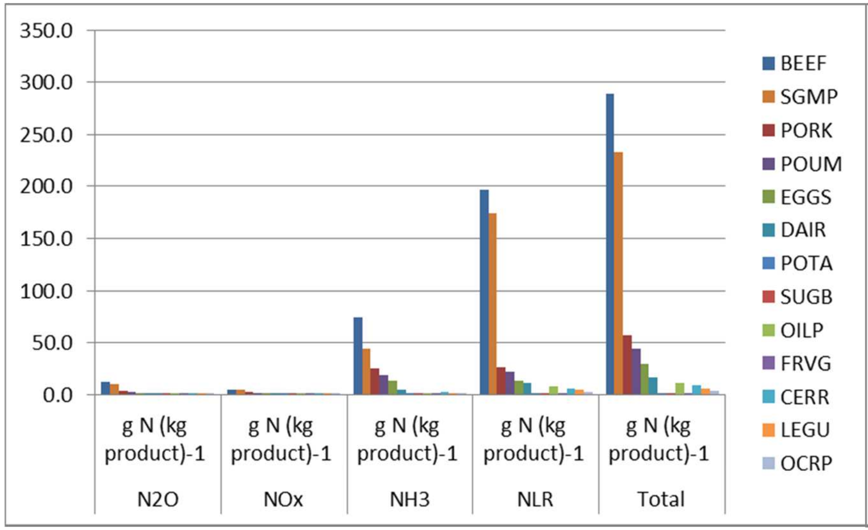
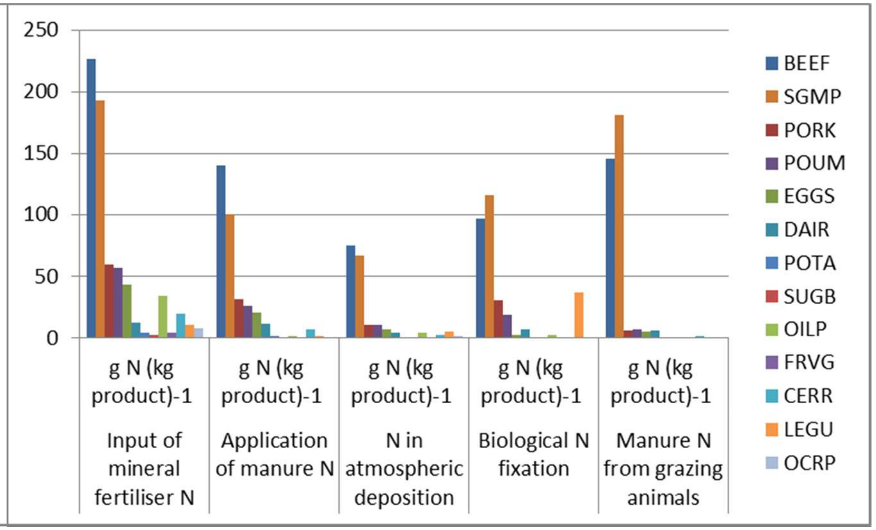
Nitrogen footprint family

c2g Nr footprints for 12 food categories in the EU

c2g N-input footprints for 12 food categories in the EU





Based on: Leip et al (2015). Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity. Environ. Res. Lett. 10, 115004

Agricultural budget and indirect flows and share caused by livestock production, feed, and feed imports

European Commission

	Total Agricultural LCA flow within EU27 territory	Total EU27 budget flow	Share agriculture
Air pollution - NH3 emissions [Tg N yr-1]	2.6	2.7	94%
Air pollution - NOx emissions [Tg N yr-1]	0.3	2.6	13%
Air pollution - SO2 [Teq yr-1]	0.021	0.35	6%
Air pollution - NOx + NH3 emissions [Tg N yr-1]	2.9	5.3	55%
Soil acidification [Tg Teq yr-1]	0.18	0.56	32%
GHG emissions [Tg CO2eq yr-1]	651	4889	13%
GHG emissions - Carbon sequestration [Tg CO2eq yr-1]	-93	-170.5	55%
GHG emissions - GHG + Carbon sequestration [Tg CO2eq yr-1]	558	4718.4	12%
Water pollution - N [Tg N yr-1]	5.4	9.1	59%
Water pollution - DIP [Tg P yr-1]	0.025	0.25	10%
Land Use [Mio km2]	1.8	4.2	42%
Loss of biodiversity [relative MSA]	-34%	-65%	51%

FAO-LEAP

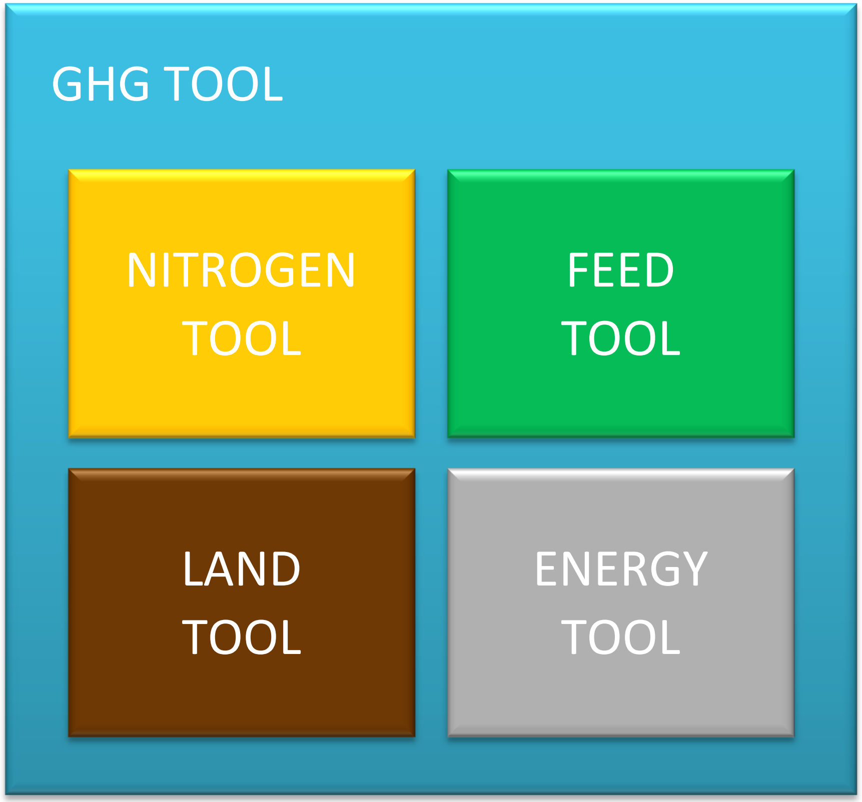
- The **Livestock Environmental Assessment and Performance** partnership (LEAP Partnership) is a multi-stakeholder initiative, with secretariat hosted at the FAO
- Proliferation of environmental assessment methods
- Based on Life cycle thinking, supply chains, eco-efficiency
- Development of LEAP-guidelines to support the harmonization in calculating and benchmarking the environmental performance of livestock supply chains and respective products
- Currently under development
  - Guidelines on Water Footprinting
  - Guidelines on Nutrient Cycles (LEAP guidelines on nutrient accounting and impact assessment in complement to previous LEAP guidelines on feed and livestock supply chains)
    - Which assessment frameworks are suited for benchmarking the environmental performance of livestock supply chains?
    - Which indicators are relevant for nutrient assessments?
    - Guidance on specific allocation (multi-cropping, crop-rotation, manure, …) and accounting 'problems' (soil stock changes, resource scarcity, …)

- Questions
  i. How far could a combination of **improved farm level technical measures** and **shifts in consumption** go to improving the Nitrogen Use Efficiency of the overall food system of Europe? And what need the incentives be in order to realize this NUE improvement?
  ii. What is the **relative potential of dietary changes and food waste reduction** to reduce nitrogen air pollution and other environmental threats?
  iii. What are the **health effects** of a range of dietary patterns that generate less nitrogen pollution (ie. positive and negative)? Potential health effects include those from air pollution and those that are nutrition related. Is it possible to identify particular dietary patterns that achieve health-environmental synergies?
  iv. To what extent can a stronger link between the scientific evidence on environment and health strengthen the case for controlling nitrogen pollution and optimizing diets to meet human health goals?

Mitigation measures

Feed and food are key!!

- Many mitigation measures have ‘systemic’ effect
- They can be monitored and implemented via relatively simple N and Feed farm-level tools



Leip, A., Carmona-Garcia, G., & Rossi, S. (in press). Mitigation measures in the Agriculture, Forestry, and Other Land Use (AFOLU) sector. Quantifying mitigation effects at the farm level and in national greenhouse gas inventories (JRC Technical Report).

UNECE-Convention on Long Range Transboundary Air Pollution (CLRTAP)
Task Force on Reactive Nitrogen
Expert Panel on N and Food

European Commission

1 PART 1: Food Chain Nitrogen Use Efficiency
1.1 The limits of Farm-scale NUE
1.2 Food losses and circular nitrogen flows in the post farm gate food chain
1.3 Full chain NUE in Europe and case studies

2 PART 2: The relevance of Nitrogen for the consumer
2.1 Dietary recommendations & nutrition scores of diet
2.2 Nitrogen-smart diet choices: Alternative protein sources
2.3 Health effect of Nr losses in the food chain

3 PART 3: Getting the consumer involved
3.1 Policies and societal changes
3.2 Nitrogen Neutrality: Concept and applications

4 PART 4: Making the case: nitrogen and food
4.1 Representative diet-pathways: the cost of unhealthy diets
4.2 Healthy and nitrogen-smart: trade-off or win-win?
4.3 Reduction of N pollution: improved supply versus changed demand

Build on the new scenario framework for climate change analysis (RCPs/SSPs/SPA), introducing consistent 'agriculture and food' storylines.

Interested to contribute??
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adrian.leip@jrc.ec.europa.eu

Conclusion

- Livestock remains to be a significant contributor to environmentally relevant emissions
- Likely both supply and demand side changes are needed if ambitious emission reduction targets are envisaged
- There is scope for emission reductions with feed and N management measures (but feed and N would need to be monitored)

Agriculture contributes between 10% (water pollution – DIP) and 59% (water pollution – N) to environmental threats

Livestock contributes between 69% (biodiversity) and 81% (global warming) – N) to agricultural relevant emissions

Thank you!

adrian.leip@jrc.ec.europa.eu