Nitrogen Cycle

Claudine Gillot

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Objectifs

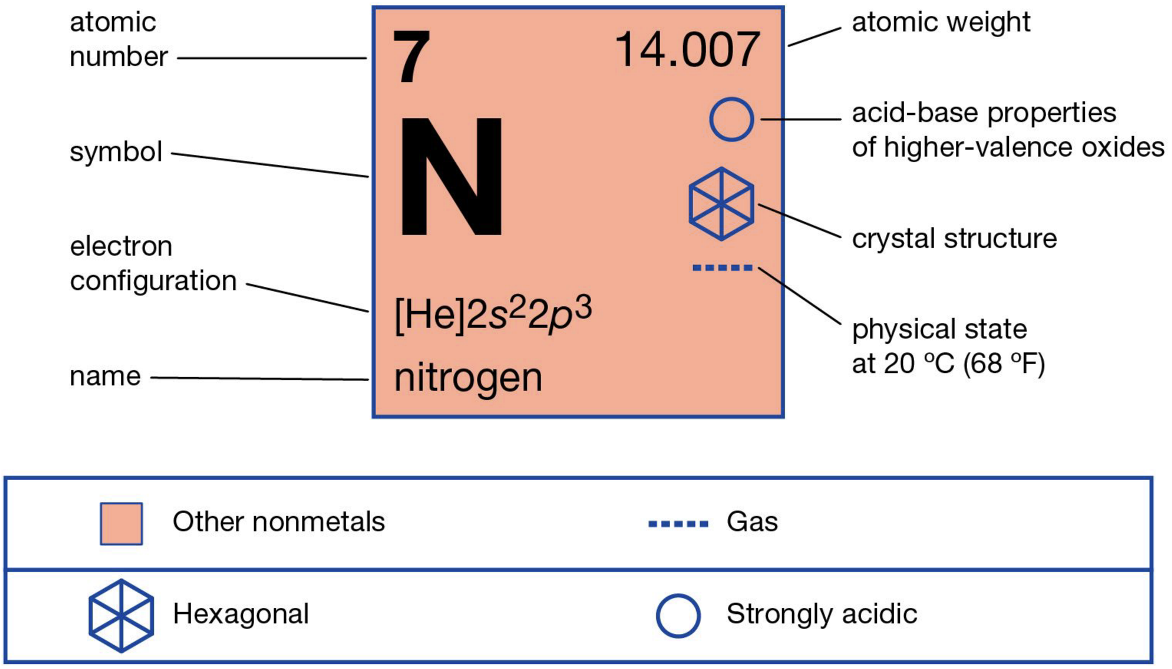
Understanding the nitrogen cycle and its impact in nature.

Introduction

Summary

Introduction

Nitrogen



Atmosphere's composition :

Dinitrogen N_2 78%

Oxygen O_2 20%

Argon Ar 9%

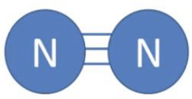
Carbon dioxyde CO_2 0,40% *

Water vapor H_2O 0-3%

Cox, Arthur N., éd. 2002. Allen’s Astrophysical Quantities. 4^{e}éd. New York : Springer-Verlag. https://doi.org/10.1007/978-1-4612-1186-0.

* "Vital signs: Carbon Dioxide". NASA Climate. May 2020. Retrieved 5 June 2020

Dinitrogen molecule



N_2, the large amount of energy required to break the nitrogen-nitrogen triple bond makes this structure stable, which is why N_2 is the most abundant in air.

Nitrogen reservoirs

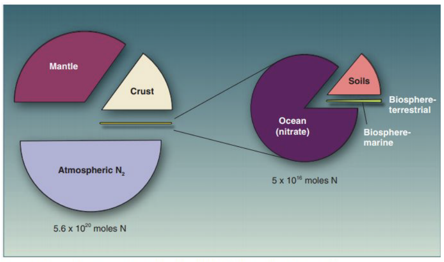


Fig. 2. The size of nitrogen reservoirs on Earth is highly variable. (*44, 64–67*).

Canfield, Donald E., Alexander N. Glazer, et Paul G. Falkowski. 2010. « The Evolution and Future of Earth's Nitrogen Cycle ». Science 330 (6001): 192-96.

https://doi.org/10.1126/science.1186120.

Nitrogen compounds

Molecule	Name	Oxidation state
C-NH_2	Organic-N	Reduced
NH_3, NH_4^+	Ammonia, Ammonium	-3
N_2H_4	Hydrazine	-2
NH_2OH	Hydroxylamine	-1
N_2	Dinitrogen	0
N_2O	Nitrous oxide	+1
NO	Nitric oxide	+2
HNO_2, NO_2^-	Nitrous acid, Nitrite	+3
NO_2	Nitrogen dioxide	+4
HNO_3, NO_3^-	Nitric acid, Nitrate	+5
		Oxidized

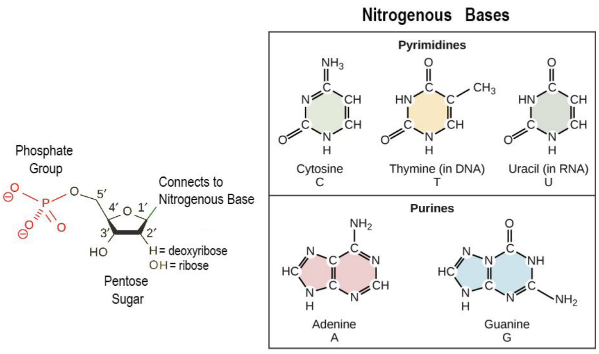
More electrons ↑ — Fewer electrons ↓

Current Biology

- Ammonium NH_4^+
- Nitrite NO_2^-
- Nitrate NO_3^-

1. Why nitrogen is important to life ?

Hint : DNA

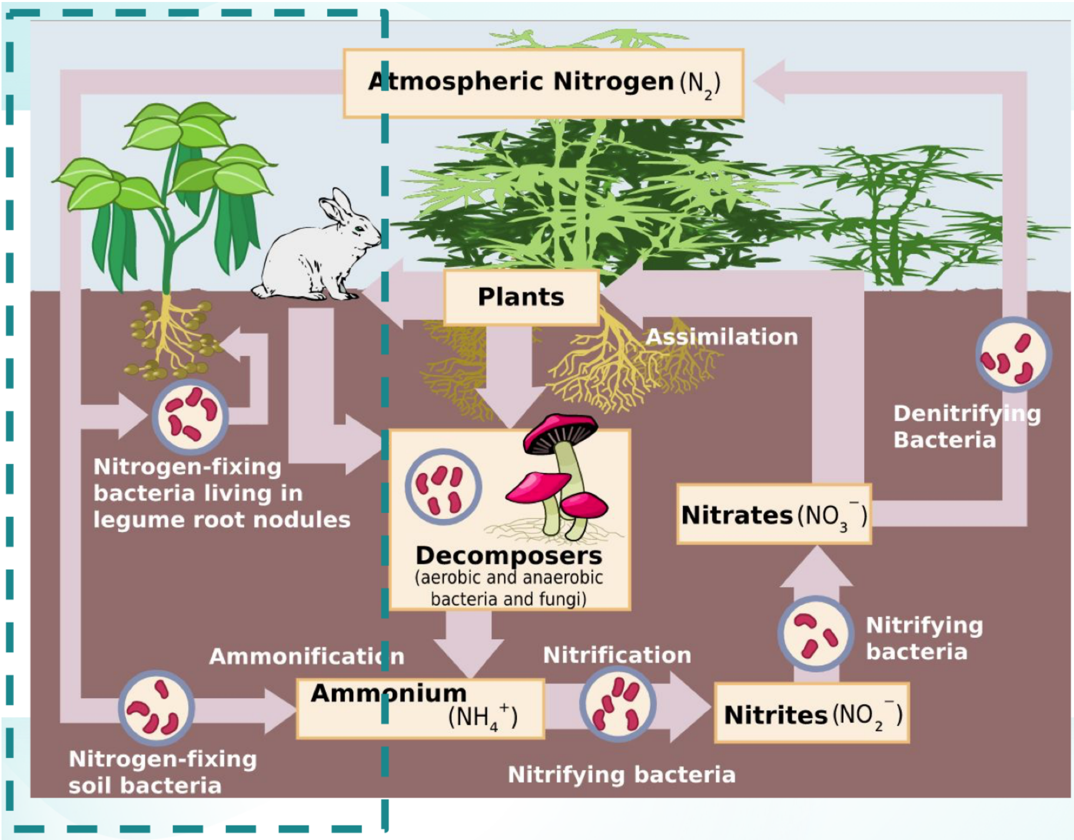


2. Medias

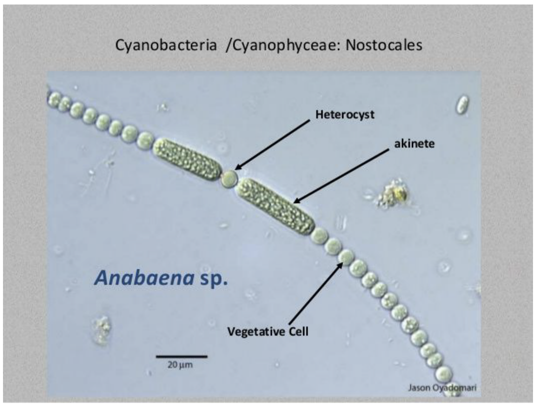
[cf. EV14_NitrogenCycle_Video1.mp4]
[cf. EV14_NitrogenCycle_Video1.mp3]

Natural nitrogen cycle

1. Biological fixation

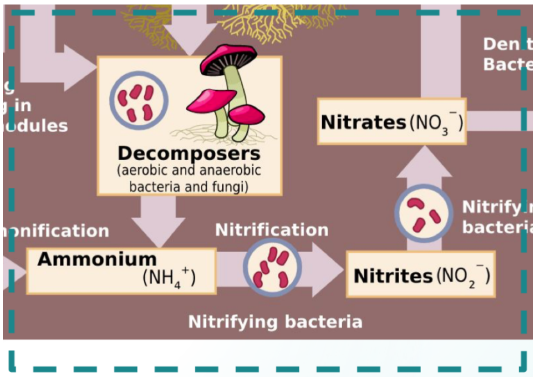


Actinomycetes



Cyanophyceae

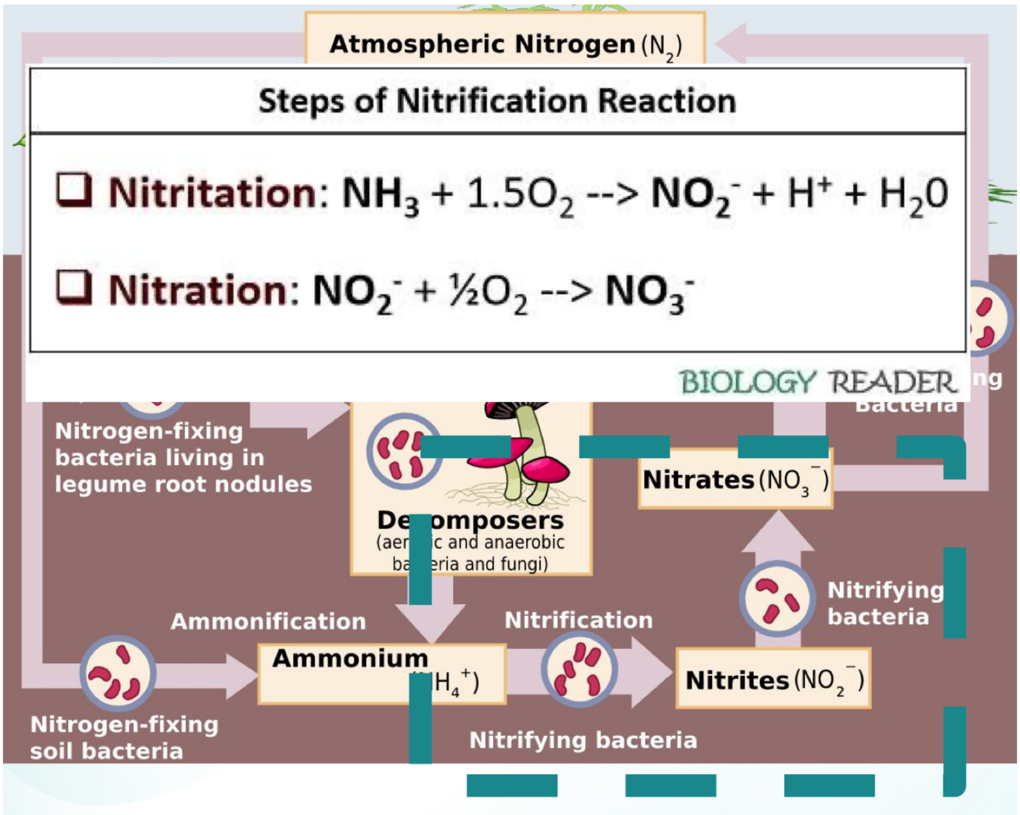
2. Mineralization



Aerobic and anaerobic conditions.

3. Assimilation by plants

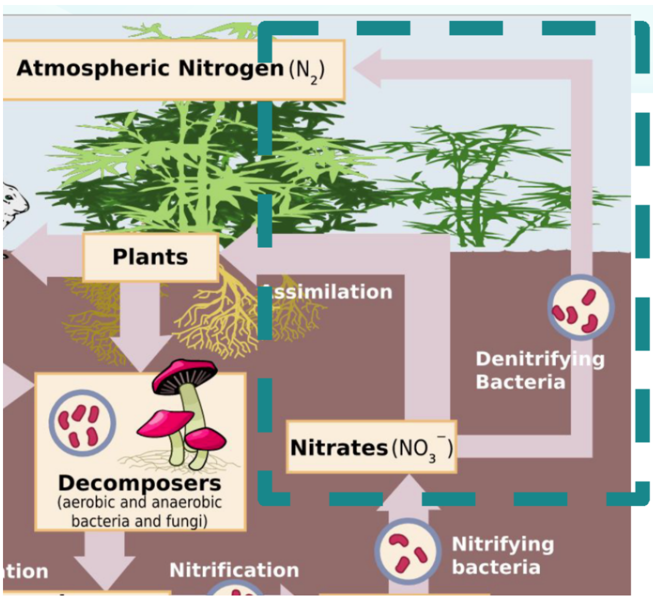
4. Nitrification



Takes place under aerobic conditions.

The activity of the microflora is optimal for pH 6.9 to 9 and temperatures between 20 and 36 °C.

5. Denitrification



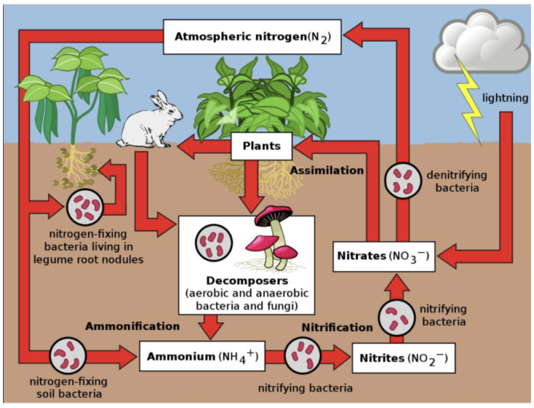
$$(1)\quad 2NO_3^- + 4H^+ + 4e^- \xrightarrow[\text{Fe, Mo}]{nar} 2NO_2^- + 2H_2O$$

$$(2)\quad 2NO_2^- + 4H^+ + 2e^- \xrightarrow[\text{Fe}]{nirS} 2NO + 2H_2O$$

$$(3)\quad 2NO + 2H^+ + 2e^- \xrightarrow[\text{Fe, Cu?}]{norB} N_2O + H_2O$$

$$(4)\quad N_2O + 2H^+ + 2e^- \xrightarrow[\text{Cu}]{nosZ} N_2 + H_2O$$

6. The role of lightning



1. Energy from lighting breaks apart N_2 into N and O_2 into O.
2. They bond to form nitrogen oxides (NOx).
3. They react with rain water to form nitrates.

7. QCM

1) What is the name of the process that oxidizes ammonium (NH_4^+) to produce nitrite (NO_2^-) and then forms nitrate (NO_3^-)?

- Denitrification
- Biological fixation
- **Nitrification**

2) Thanks to their roots, plants are able to absorb atmospheric nitrogen (N□).

- True
- **False**

3) What are the functions of nitrogen on the planet ?

- Participate in photosynthesis
- **Produce the nitrogenous bases of DNA**
- Doing cellular respiration
- Transporting Oxygen (O_2) molecules
- **Making proteins**

8. Medias

[cf. EV14_NitrogenCycle_Video2.mp4]
[cf. EV14_NitrogenCycle_Video2.mp3]

Anthropogenic nitrogen cycle

Nitrogen use in manufacturing & processing

Blanketing :

Nitrogen gas can be used to flush wine bottles both before and after filling.

https://www.generon.com/nitrogen-for-wine-sparging-bottling-blanketing/

Nitrogen generator in Beverage processing & packaging

On the picture : Juice cartons on packaging production line

https://www.peakgas.com/Articles-and-News/article/basic-nitr ogen-facts-uses-and-onsite-gas-generation

The most important use is for fertilizer

Starter fertilizer can enhance growth and yield by improving access of immobile nutrients

https://www.mississippi-crops.com/2020/03/20/top-five-management-strategies-to-improve-corn-profitability/

Nitrogen and fertilizer

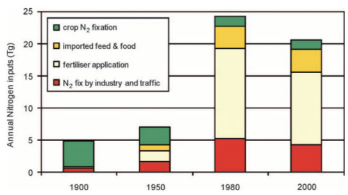


Figure SPM.1 Estimated trend of anthropogenic reactive nitrogen inputs to the European Union (EU-27) [5.1] (1 Tg equals 1 million tonnes).

The natural process of fixation of atmospheric nitrogen has been amplified by man through an increasing use of industrial fixation of atmospheric nitrogen.

The Haber-Bosch process

Video to watch :

https://www.youtube.com/watch?v=o1_D4FscMnU

The modern nitrogen cycle

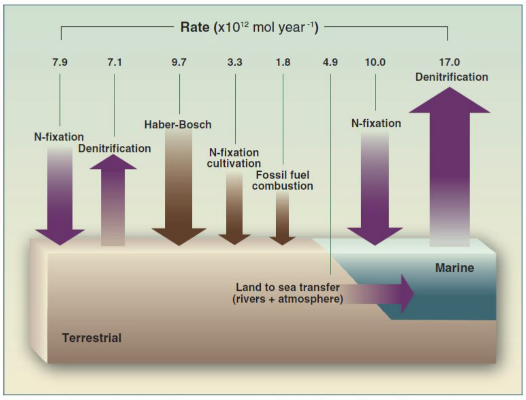


Fig. 4. Rates of nitrogen flux in the modern nitrogen cycle depend on the efficiency of the transformations between reservoirs. Arrow size reflects relative size of the flux. The dark brown arrows represent anthropogenic inputs (*25, 45, 46, 52, 53, 68, 69*).

NH_4^+ production : 9,5 x 10^12 mol

Fossil fuel combustion : 1.8 x 10^12mol

Anthropogenic sources contribute double the natural rate of terrestrial nitrogen fixation.

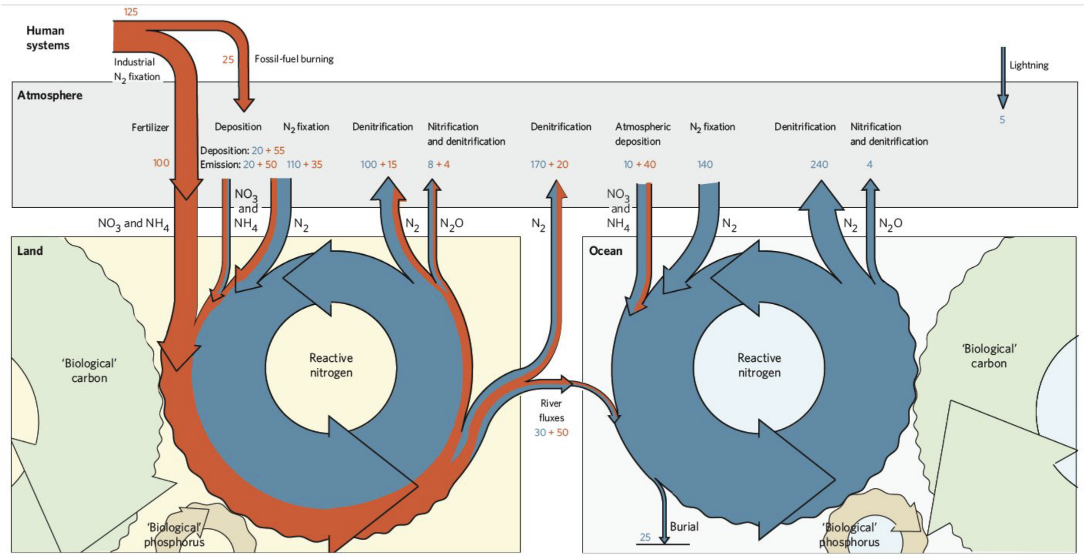


Figure 1 | Depiction of the global nitrogen cycle on land and in the ocean. Major processes that transform molecular nitrogen into reactive nitrogen, and back, are shown. Also shown is the tight coupling between the nitrogen cycles on land and in the ocean with those of carbon and phosphorus. Blue fluxes denote 'natural' (unperturbed) fluxes; orange fluxes denote anthropogenic perturbation. The numbers (in Tg N per year) are values for the 1990s (refs 13, 21). Few of these flux estimates are known to better than ±20%, and many have uncertainties of ±50% and larger[13,21].

Nitrogen and the agro-food system

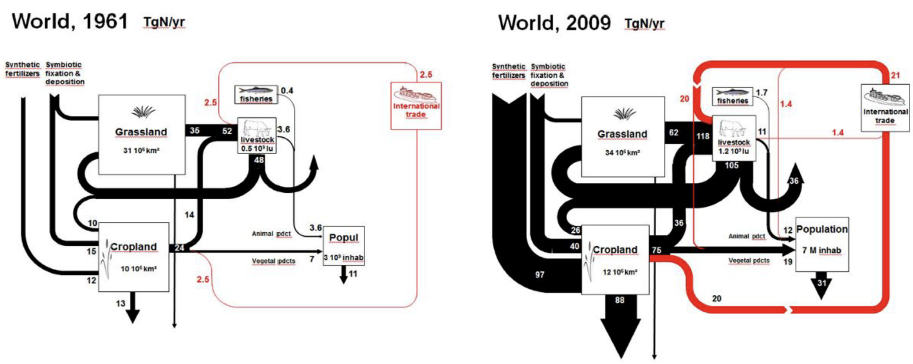


Figure 1. Generalized representation of N transfers through the world agro-food system (GRAFS) in 1961 and 2009.

Why does livestock farming produce large quantities of nitrogen-rich effluents ?

1. Conclusion

QCM

1) What is the Haber-Bosh process?

- A process that transforms air into fertilizer.
- **A process to fix atmospheric dinitrogen in the form of ammonia.**
- A process that converts ammonia into nitrate.
- **A process that permit to have available nitrogen in sufficient quantity to allow its industrialization.**

2) What are the anthropogenic sources of the nitrogen cycle?

- **Fossil fuel combustion**
- **Industrial fixation**
- Deforestation
- **Crops and livestock**
- Building construction

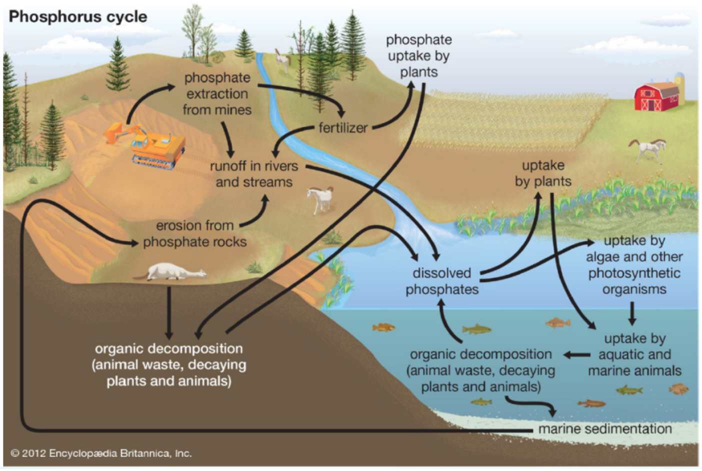
2. Medias

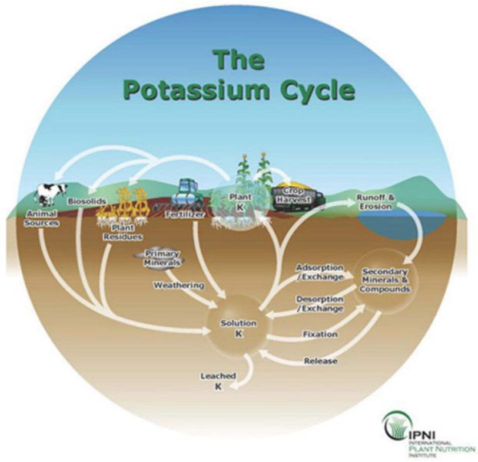
[cf. EV14_NitrogenCycle_Video3.mp4]
[cf. EV14_NitrogenCycle_Video3.mp3]

Outflows and nitrogen cascade

IV

Introduction

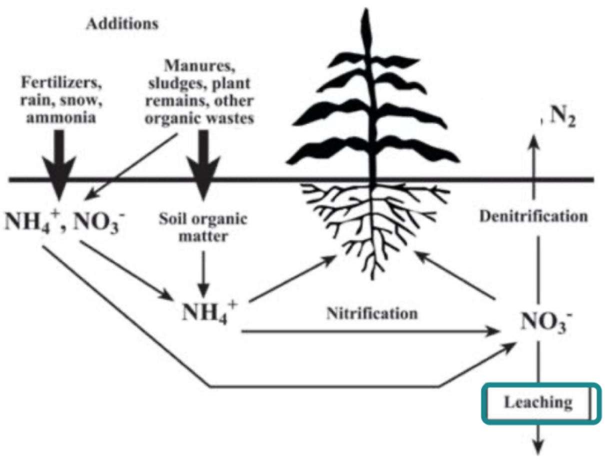




What is on of the main difference between phosphorus, potassium and nitrogen ?

Nitrate goes from the biosphere to the environment by nitrate leaching, gaseous emissions.

Nitrate leaching



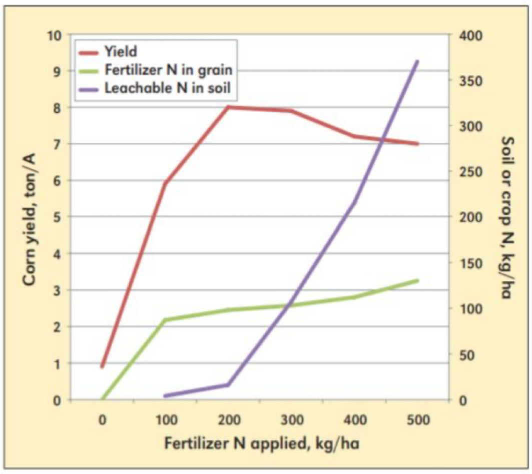


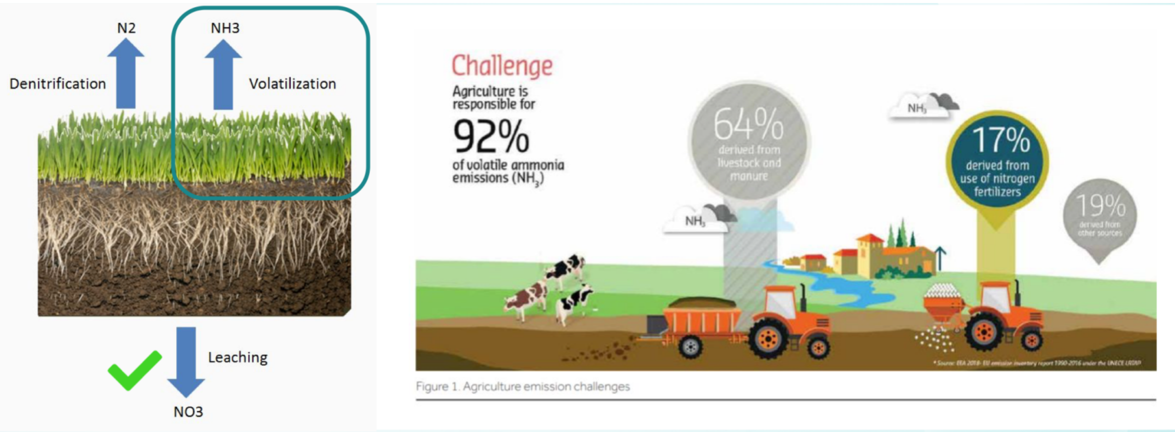
Figure 4. Nitrogen fertilizer added beyond the capacity of crops to recover it increases the risk for nitrate leaching. Broadbent and Rauschkolb, 1977.

Nitrate leaching is highly dependent on rainfall, soil type and soil nitrogen content.

Video to watch

https://www.youtube.com/watch?v=-6e_iF9d2F0

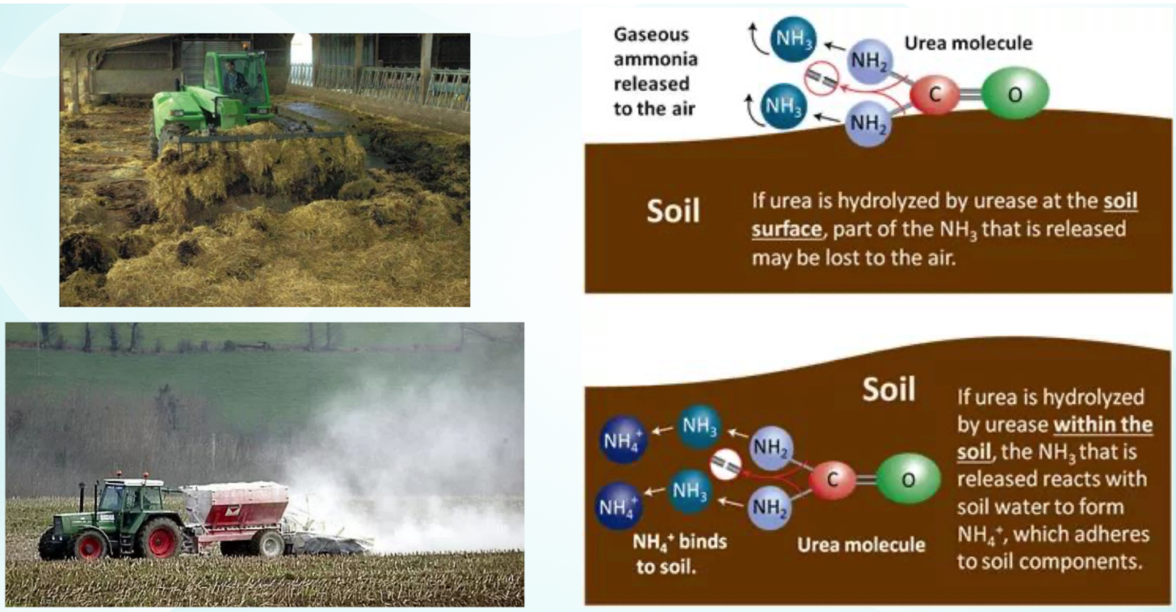
Ammonia volatilization



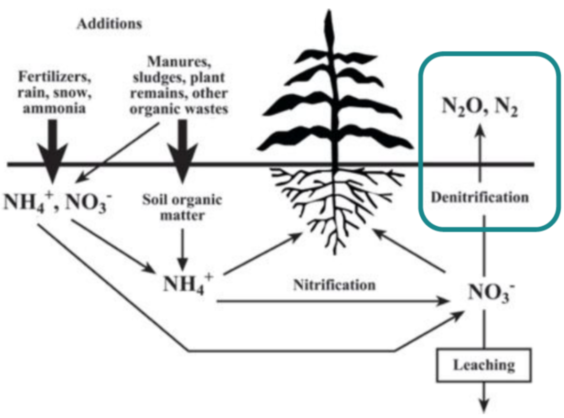
The presence of ammoniacal nitrogen in a solution in contact with air systematically leads to the volatilization of ammonia.

Volatilization depends very strongly on the physical and chemical conditions of the environment.

- the nitrogen content of the substrate in contact with the air ;
- the proportion of nitrogen present in the form of ammonia ;
- the contact surface between the solution containing ammoniacal nitrogen and the atmosphere ;
- the dispersion of the air in contact with the emission zone.



Nitrogen oxides and nitrous oxide emissions



$$(1)\quad 2NO_3^- + 4H^+ + 4e^- \xrightarrow[\text{Fe, Mo}]{nar} 2NO_2^- + 2H_2O$$

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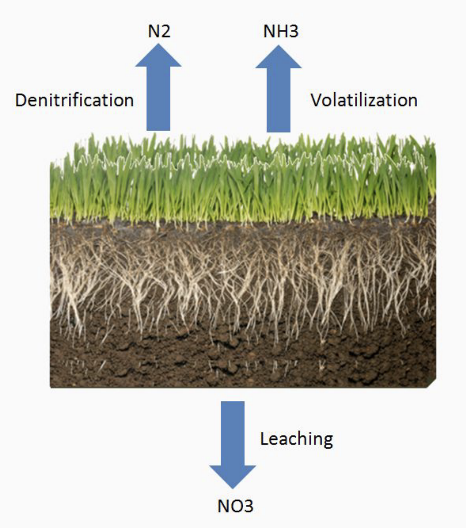
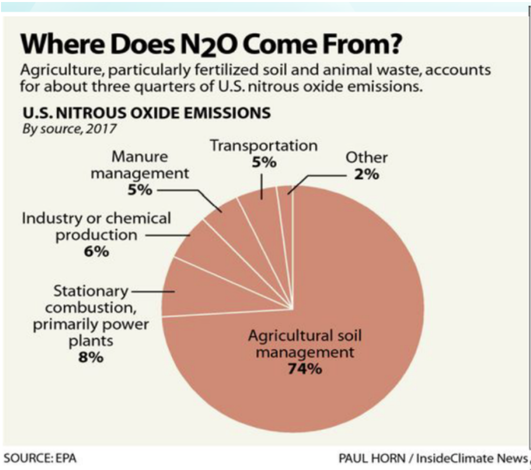
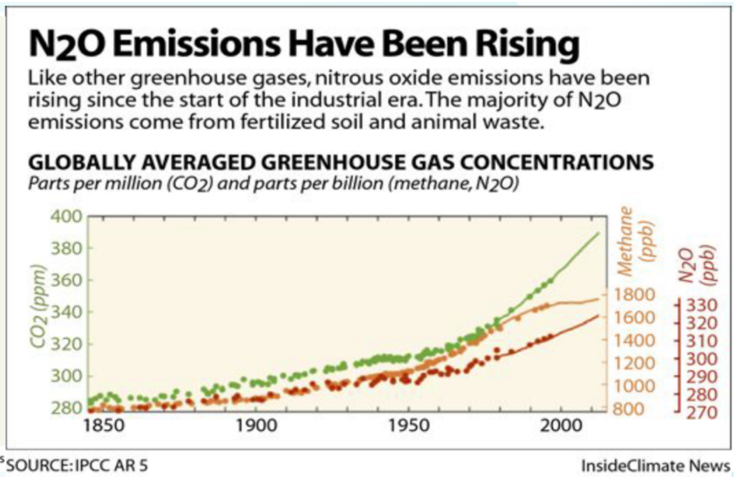


The parameters which are likely to intervene to regulate the proportion of nitrous oxide formed during denitrification are :

- the pH of the environment ;
- the nitrate concentration ;
- the soil aeration, often characterized by the water saturation rate ;
- the availability of reducing agents.

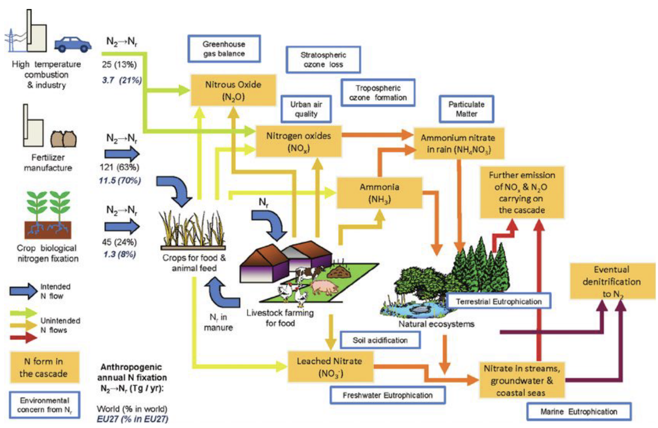




In addition to nitrous oxide emissions, there are nitric oxide emissions, rather observed in dry environments, and associated with nitrification situations.

Nitrogen oxides, mainly NOx (NO_2 and NO) and nitrous oxide (N_2O) are emitted during nitrification and/or denitrification reactions, **both in the field and in livestock buildings** (bedding, effluent storage areas).

The nitrogen cascade



Simplified view of the nitrogen cascade, highlighting the major anthropogenic sources of reactive nitrogen (Nr) from atmospheric dinitrogen (N_2), the main pollutant forms of Nr (orange boxes) and nine main environmental concerns (blue boxes). Estimates of anthropogenic N fixation for the world (Tg /yr for 2005, in black) are compared with estimates for Europe (Tg /yr for 2000, in blue italic). Blue arrows represent intended anthropogenic Nr flows; all the other arrows are unintended flows.

QCM

1) Nitrogen is characterized by a great ability to leave the soil-plant-animal cycle

- **True**
- False

2) Nitrate leaching losses increase when fertilizer applications are in excess of the crop need.

- **True**
- False

3) What is the physical and chemical condition of the environment on which the volatilization of ammonia depends?

- **the nitrogen content of the substrate in contact with the air.**
- **the proportion of nitrogen present in the form of ammonia.**
- the proportion of nitrogen present in the form of nitrate.
- **the contact surface between the solution containing ammoniacal nitrogen and the atmosphere.**
- the soil aeration.
- **the dispersion of the air in contact with the emission zone.**

1. Medias

[cf. EV14_NitrogenCycle_Video4.mp4]
[cf. EV14_NitrogenCycle_Video4.mp3]

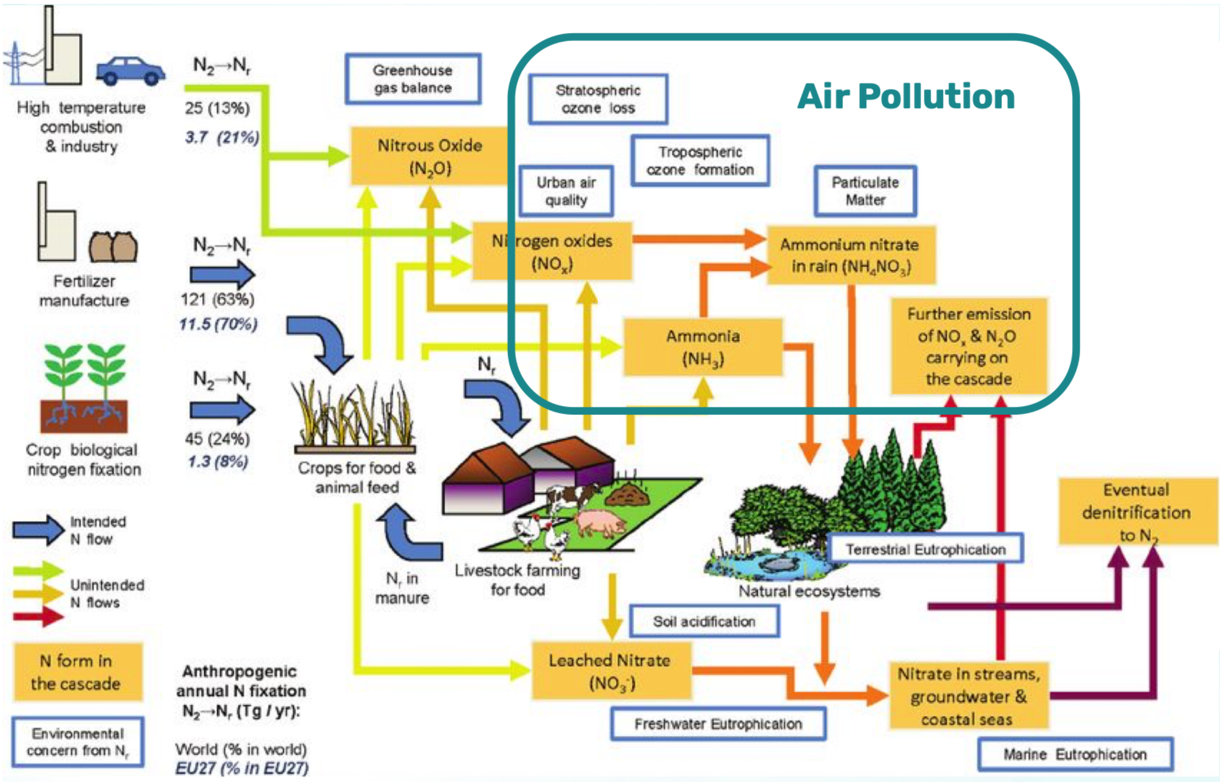
Environmental Impacts

V

Video to watch : The impact of nitrogen pollution[1]

https://www.youtube.com/watch?v=ZvKXHQM6soo[2]

The nitrogen cascade



Small reminder :

This cascade of unintentional flows of reactive nitrogen is accompanied by a cascade of harmful consequences for the environment, the climate and human health.

When reactive nitrogen returns in the form of inert atmospheric nitrogen dioxide, it has potentially crossed several compartments in several forms in excessive quantities, and thus contributed to different environmental impacts on all of our planet.

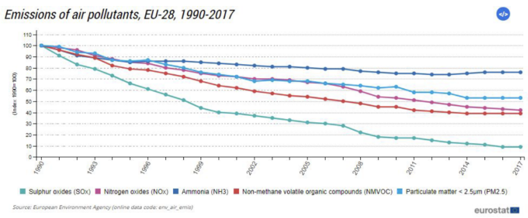
Air pollution

Table 18.1 The role of N containing compounds and ozone in air pollution effects. The threats to ecosystems from N deposition are discussed in Grizzetti *et al.*, 2011 and Dise *et al.*, 2011 (Chapter 17 (threats to water)) and Chapter 20 (threats to biodiversity))

	Effects			
Compounds	**Human health**	**Ecosystems**	**Materials**	**Visibility**
Nitrogen dioxide	X		X	X
Ammonia		X	X	
Particles NH_4^+/NO_3^-	X		X	X
Ozone	X	X	X	
N deposition		X (acidification, eutrophication)		

[1] https://www.youtube.com/watch?v=ZvKXHQM6soo

[2] https://www.youtube.com/watch?v=eJOGGvH9xkg



Regulations :

- Air quality standards
- The Convention on

  Long-Range Transboundary Air Pollution (LRTAP Convention)

Table 18.5 Overview of nitrogen related health impacts

Pollutant	Health impacts and routes	Health impacts
NO_x	Inhalation - direct impacts of NO_2 - impacts via O_3 - impacts via PM	Asthma, respiratory disorder, inflammation of air ways, reduced lung functions, bronchitis, cancers
NH_3	Inhalation: - direct impacts (negligible) - impacts via PM Odour	See NO_x Small as odour contribution by NH_3 is modest
N_2O	Health impacts from global warming, often enhanced by eutrophication	Enhancement of vectors for infectious diseases (malaria) and frequency of infestations (HAB*, insects)

* Harmful Algal Bloom

1. 1. Health impacts

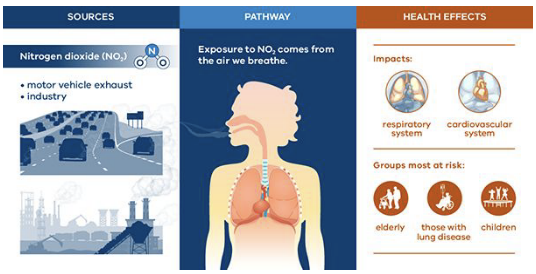
Ammonia

NH_3 - Health effects of ammonia are indirect through contribution of NH_4^+ to particulate matter (PM).

Ammonia emissions significantly contribute to the formation of secondary particulate matter in the atmosphere (~ 20% by mass).

The main source of ammonia in the atmosphere is agriculture.

Nitrogen dioxide (NO2)



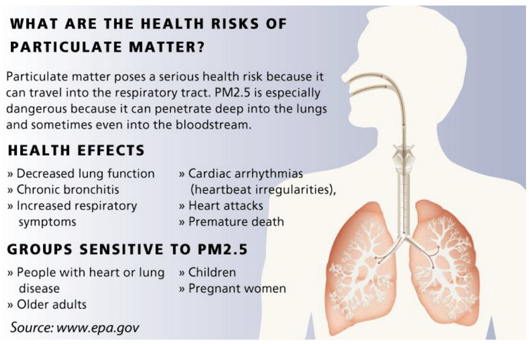
It is a toxic gas that has adverse health effects both in the long term (chronic) and short term (acute).

Data from Europe suggested that long-term concentrations of nitrogen dioxide or nitrogen oxides (NO) were associated with an increased risk of all-cause mortality.

Nitrogen dioxide is strongly related to particulate matter.

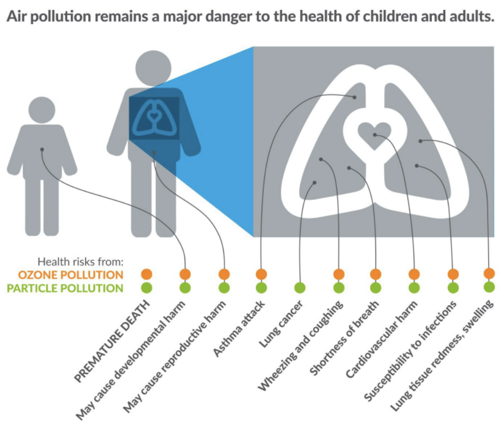
https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/nitrogen-dioxide-in-the-air

Particulate matter (PM)



NO_2 and NH_3 - Reactive nitrogen contributes to particle mass and to the adverse health effects caused by the PM.

Ozone



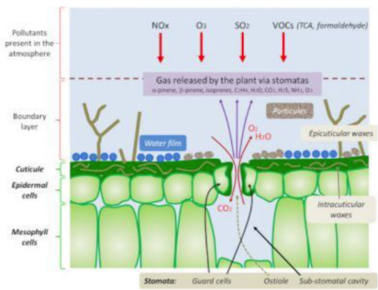
NO_2 and NH_3 - Reactive nitrogen contributes to particle mass and to the adverse health effects caused by the PM.

https://www.lung.org/research/sota/health-risks

2. Ecosystems

Ammonia

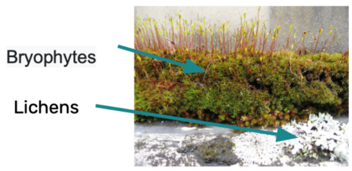
	Effects
Compounds	**Ecosystems**
Nitrogen dioxide	
Ammonia	X
Particles NH_4^+/NO_3^-	
Ozone	X
N deposition	X (acidification, eutrophication)



Atmospheric ammonium is absorbed by the leaves of plants. More precisely through the stomata, where gas exchanges take place.

Atmospheric ammonium is absorbed by the leaves of plants. More precisely through the stomata, where gas exchanges take place.

Before reaching the leaf, the pollutant will first have to pass through the “boundary layer”.

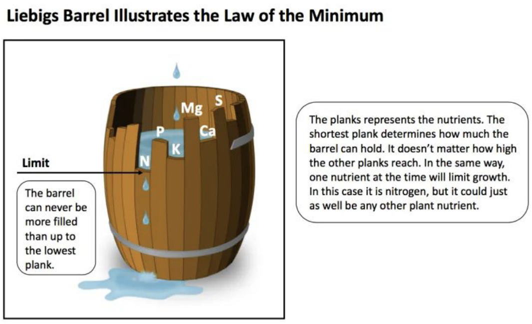


Algae on a tree in Moninea Bog in Co Fermanagh, where lichen and sphagnum moss were killed by ammonia.

Lichens are very affected by atmospheric pollution because they not have a impermeable cuticle.

Lichens and bryophytes are an important part of the ecosystem integrity.

https://www.irishtimes.com/news/science/the-trouble-with-ammonia-1.3721098



Ammonia acts as a macro-nutrient and at low exposure levels plants respond by increasing their biomass production.

Because plant growth is often limited by the supply of nutrient nitrogen, and so any increases in growth may lead to negative effects on community composition.

The fertilisation effect can at higher exposure levels lead to secondary long-term adverse effects including increased susceptibility to abiotic (drought, frost) and biotic stresses.

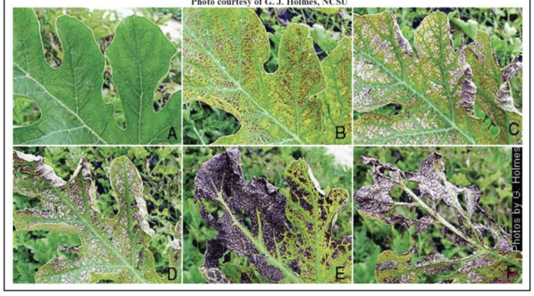
Oxides of nitrogen

Oxides of nitrogen can have a fertiliser effect, but can also be toxic to plants, depending on concentrations.

At low concentrations typical of ambient conditions, nitrogen oxides is more phytotoxic than nitrogen dioxide.

As for ammonia, the growth stimulation was also considered as potentially adverse for (semi-) natural vegetation owing to potential negative effects on community composition.

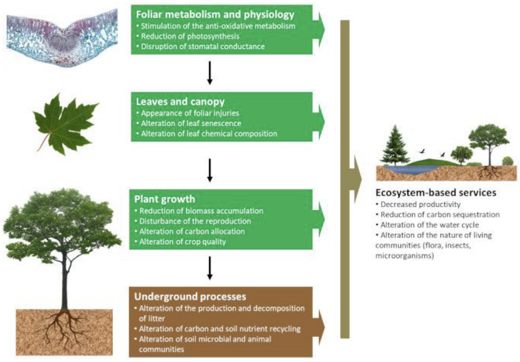
Fig. 2 Progression of ozone damage (A=none to F=severe) on watermelon foliage.
Photo courtesy of G. J. Holmes, NCSU



Today ozone is considered to be the most important gaseous pollutant causing effects on vegetation.

Besides visible injuries on leafs and needles, ozone also causes premature leaf loss, reduced photosynthesis and reduced leaf, root, and total dry weights in sensitive plant species.

https://extension.umd.edu/learn/air-pollution-effects-vegetables



Today ozone is considered to be the most important gaseous pollutant causing effects on vegetation.

Besides visible injuries on leafs and needles, ozone also causes premature leaf loss, reduced photosynthesis and reduced leaf, root, and total dry weights in sensitive plant species.

This leads to significant decrease in productivity of some agricultural crops and to reduced forest production.

Effects of ozone on vegetation: from plant cells to ecosystems. [Source: © J.P. Garrec]

Effects on materials

Table 18.1 The role of N containing compounds and ozone in air pollution effects. The threats to ecosystems from N deposition are discussed in Grizzetti *et al.*, 2011 and Dise *et al.*, 2011 (Chapter 17 (threats to water)) and Chapter 20 (threats to biodiversity))

	Effects			
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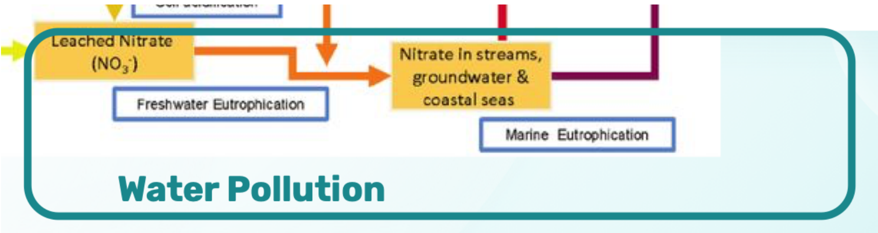
Ammonia		X	X	
Particles NH_4^+/NO_3^-	X		X	X
Ozone	X	X	X	
N deposition		X (acidification, eutrophication)		

Corrosion of materials was originally mostly associated with air pollution by sulphur dioxide; however know that nitric acid (HNO3), ozone and particulate matter also contribute significantly to the negative effect of air pollution on materials.

The lifetime of technological products is shortened because of air pollution.

3. Water Pollution



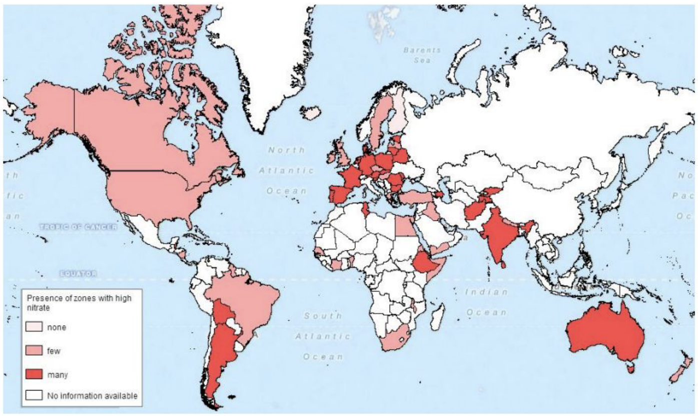
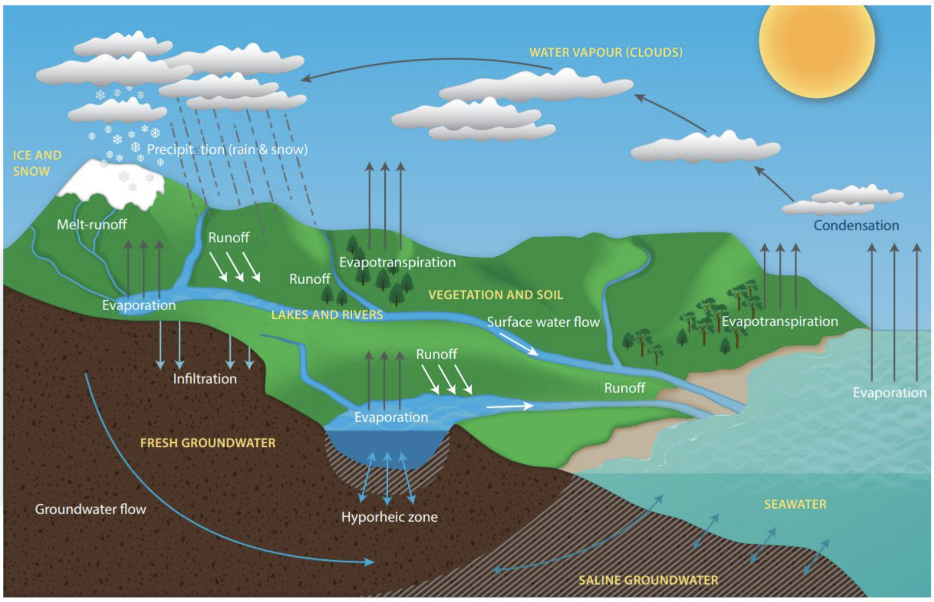
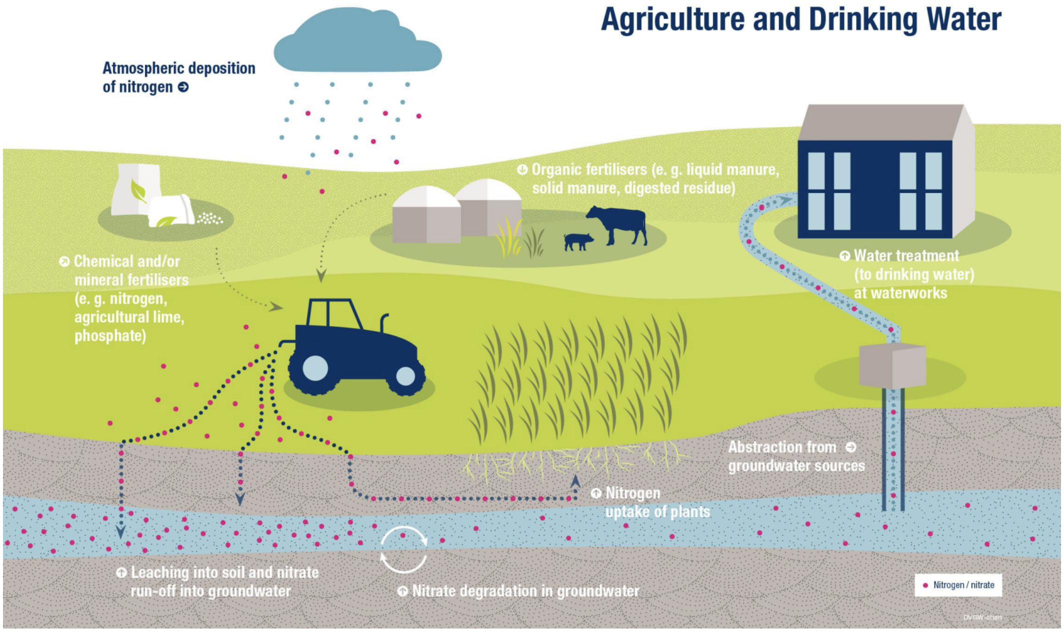


Figure 2 Global map with the presence of zones with high nitrate in groundwater (source: IGRAC, 2012)

The water cycle – also known as the hydrological cycle



How does nitrogen get into drinking water?



https://www.dvgw.de/english-pages/topics/water/nitrates-and-drinking-water/

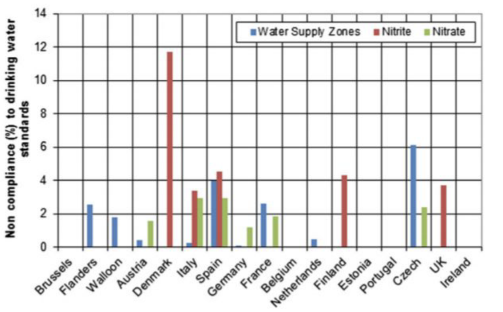


Figure 3.2 Noncompliance for EU legal standards for nitrite and nitrate in drinking water (exceedance in more than 1% of all samples taken) between 2000 and 2004 and the associated proportion of Water Supply Zones (WSZ). *European Commission: the quality of drinking water in the European Union, 2002–2004. Synthesis report for EU Directives 80/778/EEC and 98/83/EC; 2007. [http://circa.europa.eu/Public/irc/env/drinking_water_rev/library?l=/drinking_synthesis/report_2002-2004pdf/_EN_1.0_&a=d].* For color version of this figure, the reader is referred to the online version of this book.

The regulatory level is usually met for public water supplies, which are routinely monitored.

In the EU, noncompliance to the nitrate or nitrite standards in large public supplies is reported regularly but rarely exceeds □% of the sample population.

Bryan, Nathan S., et Hans van Grinsven. « The Role of Nitrate in Human Health ». In Advances in Agronomy, 119:153-82. Elsevier, 2013.https://www.sciencedirect.com/science/article/abs/pii/B9780124072473000032?via%3Dihub[1]

Effects of nitrogen rich drinking water on human health

Nitrate itself is generally considered to be harmless at low concentrations.

Nitrite, on the other hand, is reactive especially in the acid environment of the stomach where it can nitrosate other molecules including proteins, amines and amides.

[1] 2013.https://www.sciencedirect.com/science/article/abs/pii/B9780124072473000032?via%3Dihub

Eutrophication

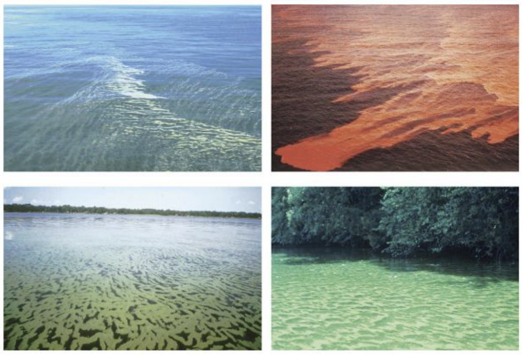
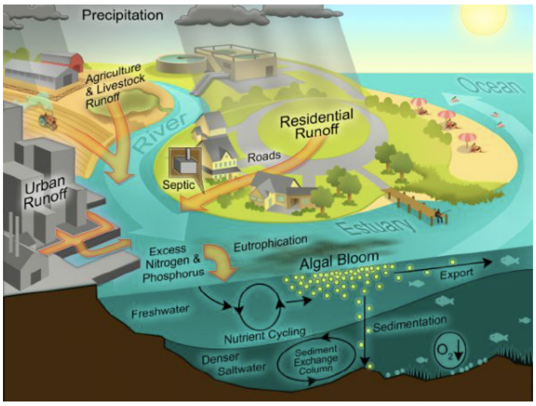


Fig. 1. Examples of estuarine and coastal phytoplankton blooms symptomatic of nutrient-driven eutrophication. Upper left: a bloom of the nitrogen-fixing blue-green algae (cyanobacteria) *Nodularia* spp., *Aphanizomenon flos aquae* and *Anabaena* spp. in the Gulf of Finland, Baltic Sea (photograph courtesy of P. Moisander). Upper right: red tide dinoflagellate bloom, in coastal Japan (Courtesy of ECOHAB Program). Lower left: a mixed cyanobacterial bloom comprised of nitrogen fixers (*Anabaena* spp.) and a non-nitrogen fixing nuidance species, *Microcystis aeruginosa*, in the St. Johns River, a tidal estuary in Florida, USA. Lower right: a mixed algal bloom dominated by non-nitrogen fixing cyanobacteria (*Microcystis aeruginosa*, *Oscillatoria* spp.) and green algae (chlorophytes) in the upstream oligohaline segment of the Neuse River Estuary, NC.

- Is one of the most common alterations of continental and marine waters.
- Result in an exacerbated productivity of aquatic ecosystems due to an excessive nutrient inputs.



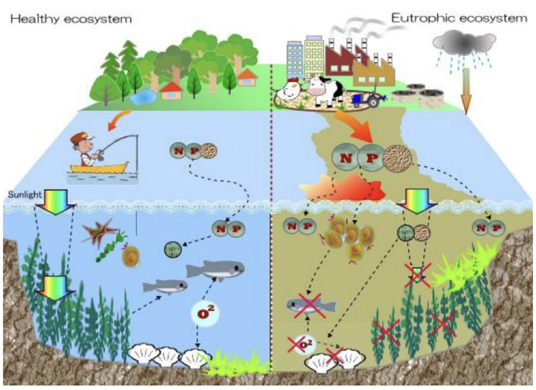
Factors controlling eutrophication can be summed up as a combination of some or all of the following interacting factors:

- An excess of nutrients
- A long water residence time
- A sufficient amount of light
- A favourable temperature

Fig. Functional linkages between hydrology, anthropogenic nutrient inputs, eutrophication (phytoplankton blooms), and hypoxia/anoxia

in estuarine and coastal aquatic ecosystems.

Paerl, Hans W. « Assessing and Managing Nutrient-Enhanced Eutrophication in Estuarine and Coastal Waters: Interactive Effects of Human and Climatic Perturbations ». Ecological Engineering 26, no 1 (janvier 2006): 40-54.



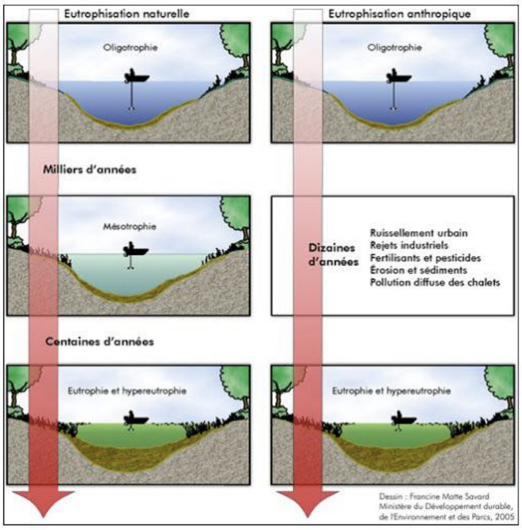
1. The increase in nutrients leads to a strong increase in primary productivity.
2. The new limiting factor becomes light.
3. The light penetration decreasing by self-shading as the biomass produced increases.
4. Development of more competitive species, which affects a change in primary producer communities, which changes the ecosystem and affects biodiversity.

https://www.unenvironment.org/nowpap/what-we-do/prevent-and-reduce-pollution/eutrophication

Video to watch

Eutrophication and dead zones | Ecology | Khan Academy

https://www.youtube.com/watch?v=AxaWXWd2pw4

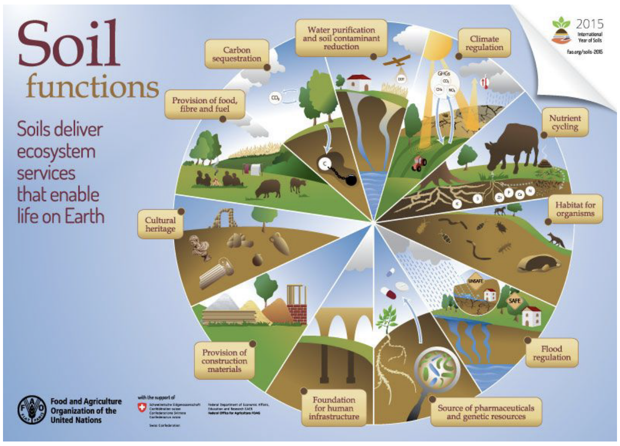


- A natural eutrophication phenomenon.

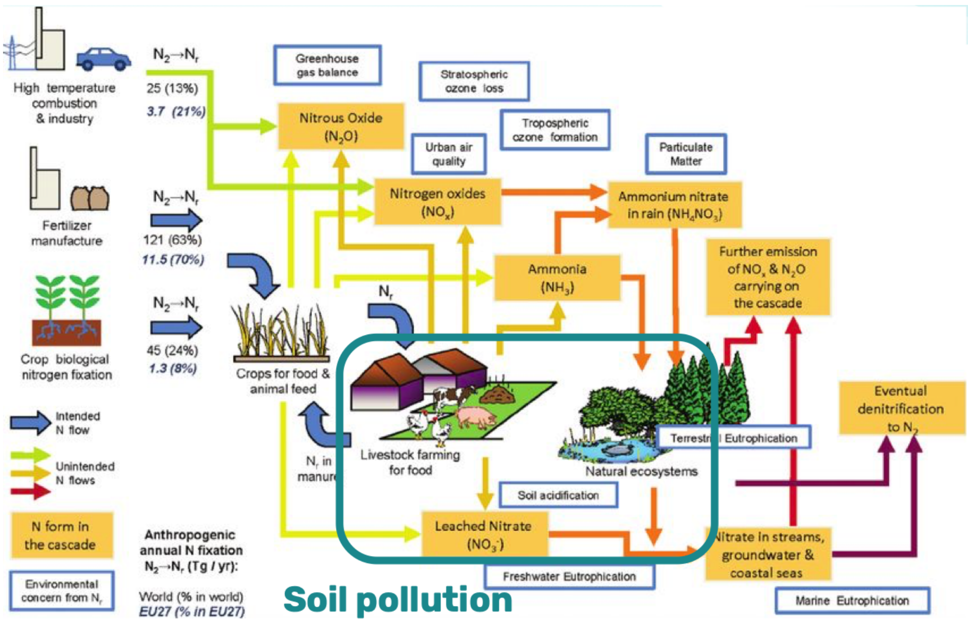
The difference between natural and anthropogenic eutrophication is time.

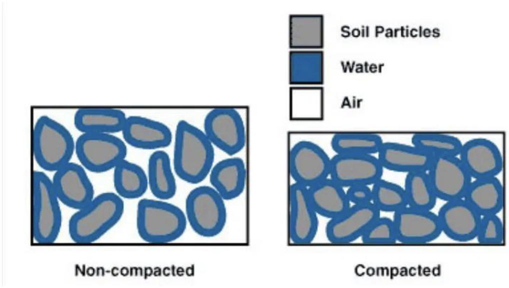
4. Soil pollution

Soil quality and functions



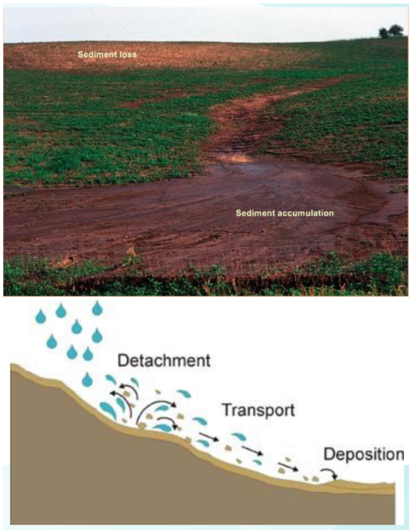
Effect of soil degradation on nitrogen





- the effects of soil compaction.

https://civilblog.org/



- the effects of erosion.
    1. Loss of productivity and sediment accumulating due to erosion sometimes can be seen in the same field as showing in this photo.
    2. Rain enhances the translocation of soil through the process of splashing. Individual raindrops detach soil aggregates and redeposit particles. The dispersed particles may then plug soil pores, reducing water intake. Once the soil dries, these particles develop into a crust at the soil surface and runoff is further increased.

https://wiki.ubc.ca/

- the effects of salinisation.

  High salt concentrations inhibit biological nitrogen transformations in soil, as well as nitrogen fixing capacity by legumes.

  https://www.quora.com/

- the effects of soils contamination.

  https://www.worldatlas.com/

- the effect of organic matter decline.

  Figure. The vicious cycle of depletion in soil organic matter-decline in

  crop yield-food insecurity-soil

  Vicente Vicente, José. « Soil organic carbon sequestration in Andalusian olive groves: effect of the managements on soil organic carbon dynamics », 2017.

Effect of nitrogen on soil

Table 21.1 Effects of N on soil parameters of natural soils, their mechanisms, and the ecosystem response

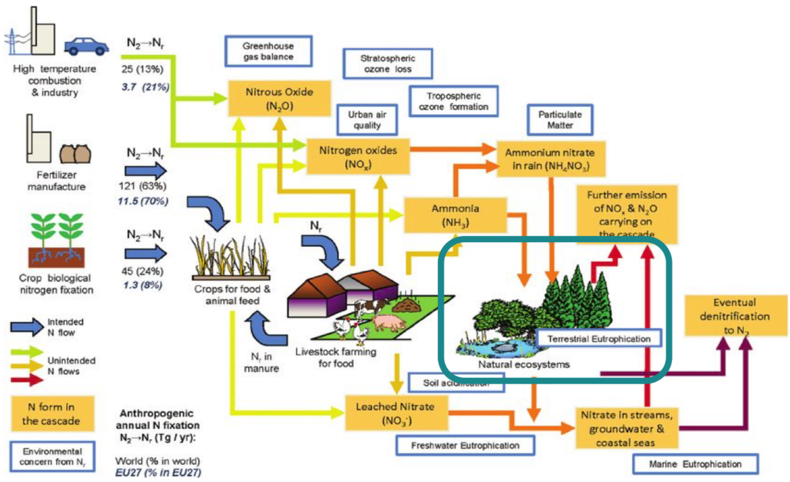
Soil parameter	Mechanism	Ecosystem response	Literature
C/N ratio	Narrows at sites with high N availability, due to the incorporation of surplus N in soil organic matter.	Plant species richness ↕ Decomposition of SOM ↕ Microbial biomass ↑	(Von Oheim *et al.*, 2008) (Friedel *et al.*, 2008) (Dumortier *et al.*, 2002) (Berg, 2000)
Inorganic nitrogen concentration	Nitrogen deposition is close to or exceeds ecosystem N demand. Input of inorganic N increases soil solution concentrations.	Plant productivity ↑ Leaf/needle N content ↑ Litter decomposability ↑ Plant species richness ↓ Vascular plants in wetlands ↑ Microbial N immobilisation ↓ Nitrogen leaching ↑ Soil N_2O/NO emissions ↑	(De Vries *et al.*, 2006b) (Corré *et al.*, 2007) (Kreutzer *et al.*, 2009) (Gundersen *et al.*, 2006) (Stevens *et al.*, 2006)
Acidification and soil buffering capacity	Nitrification of deposited NH_3/NH_4^+ leads to H^+ formation. In the course of the acidification process base cations are leached.	Nutrient availab. (Ca/Mg) ↓ Al/Mn toxcity if soil pH<5.5 ↑ Biodiversity ↓ Microbial activity ↓ Root growth ↓ Nitrogen leaching ↑ DOC leaching ↓ Soil N_2O/NO emissions ↑ Wetland CH_4-emissions	(Matzner and Murach, 1995) (Raubuch and Beese, 2005) (Bowman *et al.*, 2008) (Gauci *et al.*, 2005) (Evans *et al.*, 2008)
Soil C stocks and SOC stratification	Surplus N decreases fine root biomass and, thus, reduces belowground litter production, but increases aboveground plant production and litter fall.	Total soil C stocks ↑ Forest floor C stocks ↑ Mineral soil C stocks ↕	(Högberg, 2007) (De Vries *et al.*, 2006b) (Hyvönen *et al.*, 2007, 2008)
Soil aggregation	N can increase litterfall and improve litter quality and, thus, positively affect soil fauna and the formation of organo-mineral soil aggregates by e.g. earthworm activities	Soil aeration ↑ Water infiltration ↑	(Lavelle *et al.*, 2007)

5. Nitrogen as a threat to biodiversity

5.1. What is biodiversity ?

Video to watch :

https://www.youtube.com/watch?v=GK_vRtHJZu4&t=36s



Ecosystems can be defined by both their sensitivity and their

vulnerability to a stress such as enhanced nitrogen deposition.

The major impacts of nitrate deposition on terrestrial ecosystem

diversity are through :

- eutrophication,

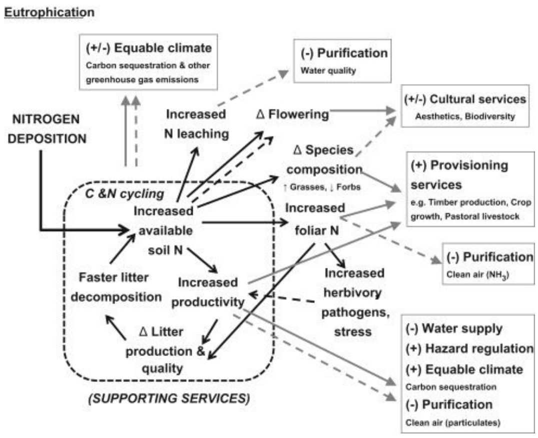


Fig. 1. Process-based impact pathway for eutrophication. Black arrows indicate process-based links, grey arrows show links to ecosystem services, where + and – indicate the nature of relationship and examples are given in small type. Solid arrows represent positive relationships and dashed arrows negative relationships. The dotted line box encompasses processes linked to C and N cycling (=Supporting Services). Impacts on species composition are generalised to increases in graminoids and decreases in forbs, but in reality are much more complex.

- acidification,

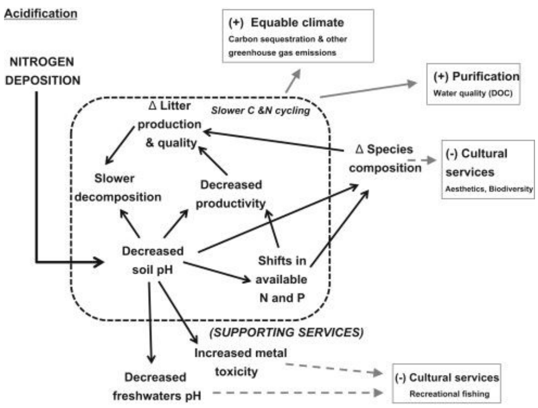


Fig. 2. Process-based impact pathway for acidification.

- direct foliar impacts,

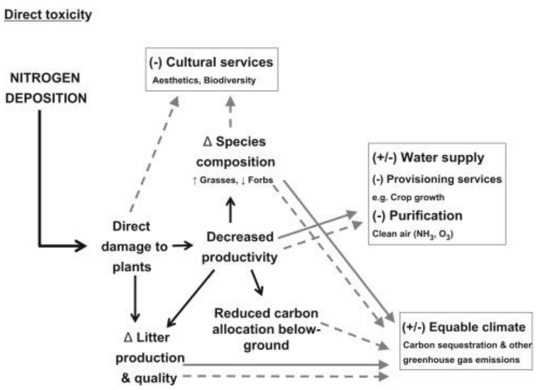


Fig. 3. Process-based impact pathway for direct toxicity (incorporating NOx and NH_3 effects).

- exacerbation of other stresses.

Jones, L., A. Provins, M. Holland, G. Mills, F. Hayes, B. Emmett, J. Hall, et al. « A Review and Application of the Evidence for Nitrogen Impacts on Ecosystem Services ». Ecosystem Services 7 (1 mars 2014): 76-88. https://doi.org/10.1016/j.ecoser.2013.09.001.

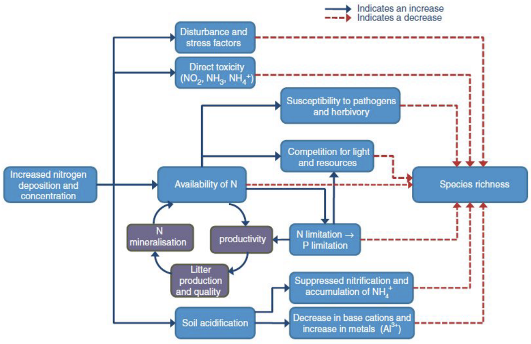


Figure. Schematic of the main impacts of enhanced N deposition on ecosystem processes and species richness. Stress is considered to occur when external constraints limit the rate of production of vegetation; disturbance consists of mechanisms that affect plant biomass by causing its partial or total destruction.

Sutton, Mark A., éd. *The European Nitrogen Assessment: Sources, Effects and Policy Perspectives*. Cambridge: Cambridge Univ. Press, 2011.

Example : Red-backed shrike

6. Medias

[cf. EV14_NitrogenCycle_Video5a.mp4]
[cf. EV14_NitrogenCycle_Video5a.mp3]

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