Review of the Gothenburg Protocol: Answers from ICP IM on questions from the CLRTAP Working Group on Strategies and Review

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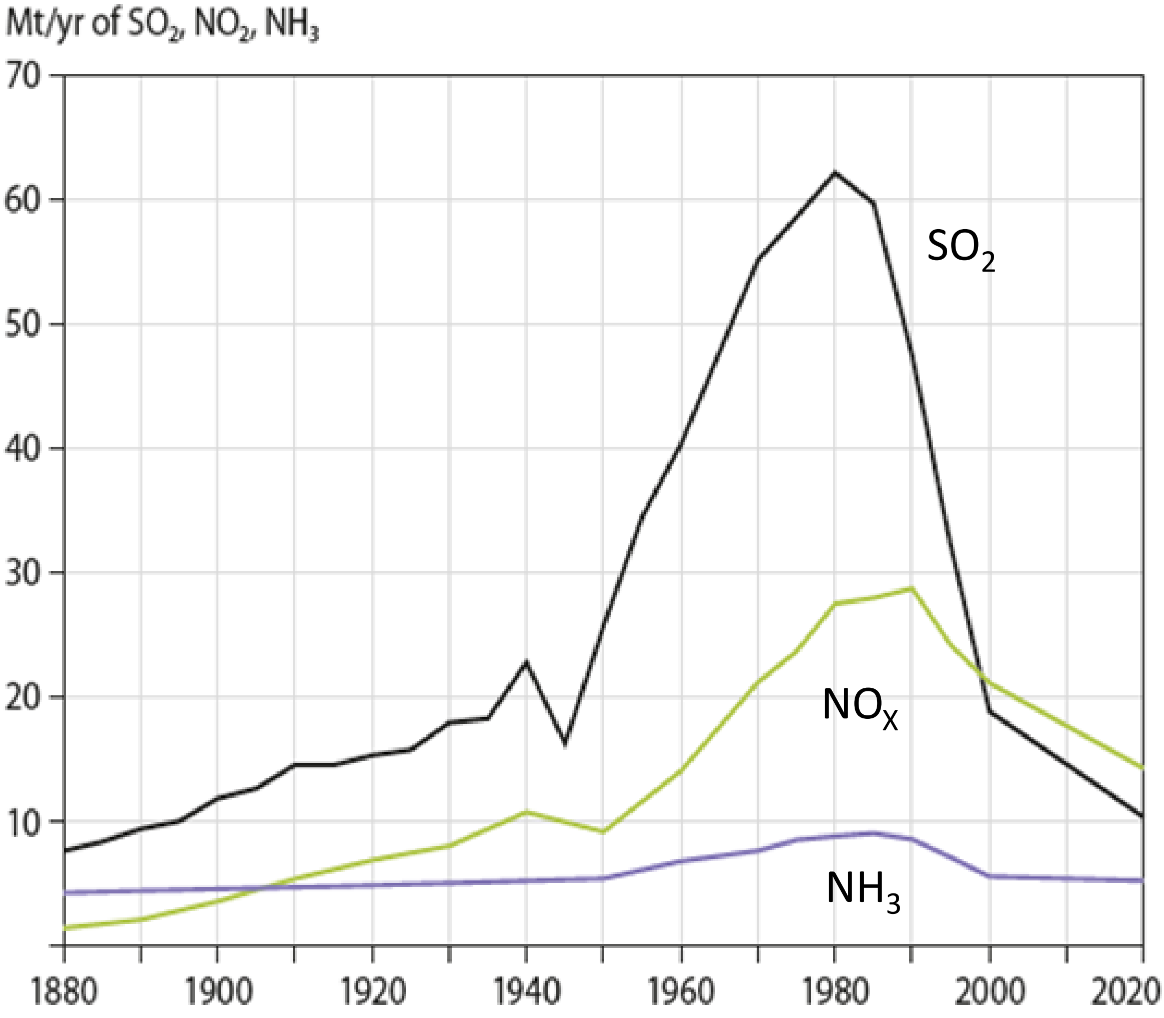
wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

Background

- The Gothenburg Protocol of CLRTAP is currently under a review process
- A Policy Review Group (PRG) has prepared key questions to be answered by the different technical bodies of the Convention
- This information will be used to derive new emission reduction targets for the Convention, as well provide other information for developing the work
- The ICP IM Programme Centre has compiled first short answers to the different questions relevant for ICP IM
- This information will be updated before the next meeting of the WGE

European emissions of SO_2, NO_X and NH_3



Grennfelt et al. 2020, https://doi.org/10.1007/s13280-019-01244-4

Question

2.2.b. What is the annual change (or change every 5 years) in exceedance of critical loads for acidification and eutrophication between1990 and 2018/2019 in terms of percentage ecosystems with exceedances and accumulated excess, based on current critical loads. What are projected changes up to 2030 and beyond?

Key reference used to derive answer:

Forsius, M., et al. 2020. Assessing critical load exceedances and ecosystem impacts of anthropogenic nitrogen and sulphur deposition at unmanaged forested catchments in Europe. *Science of The Total Environment* 753: 141791. https://doi.org/10.1016/j.scitotenv.2020.141791

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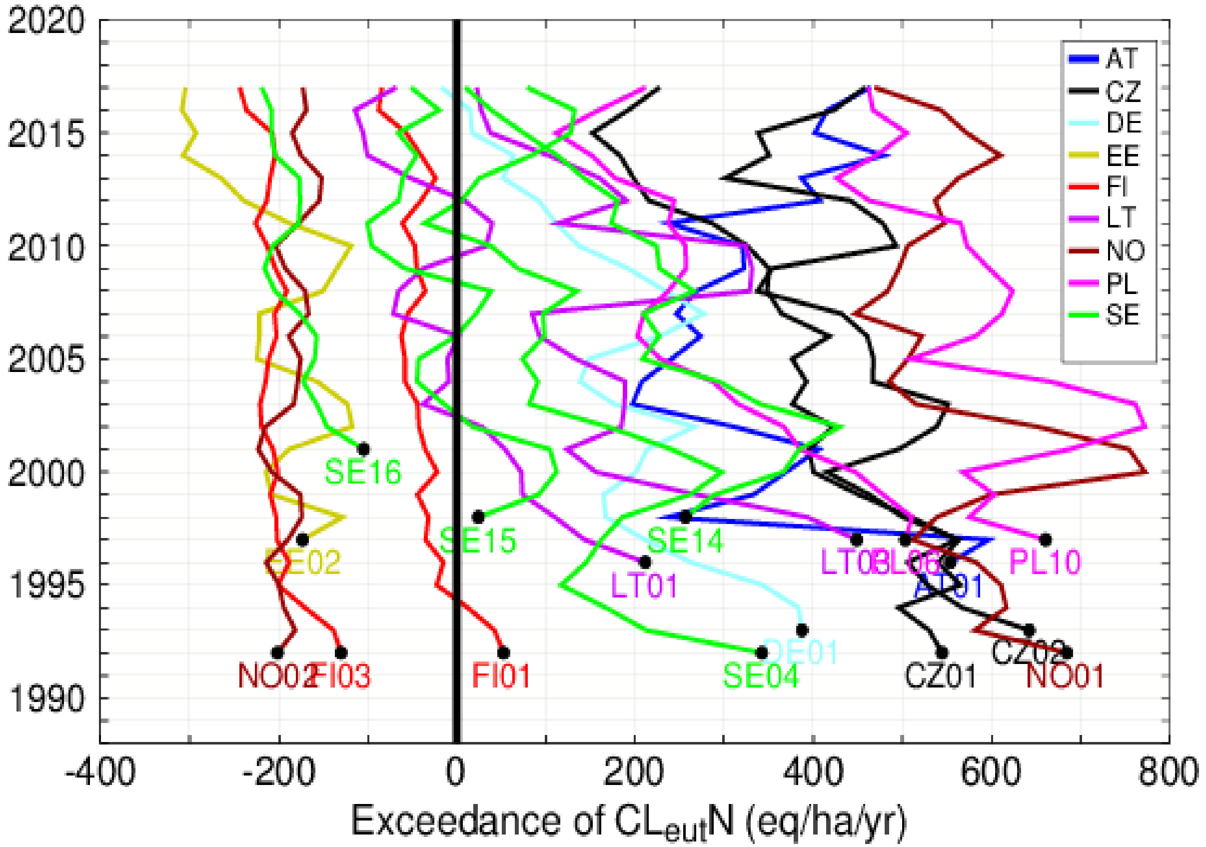
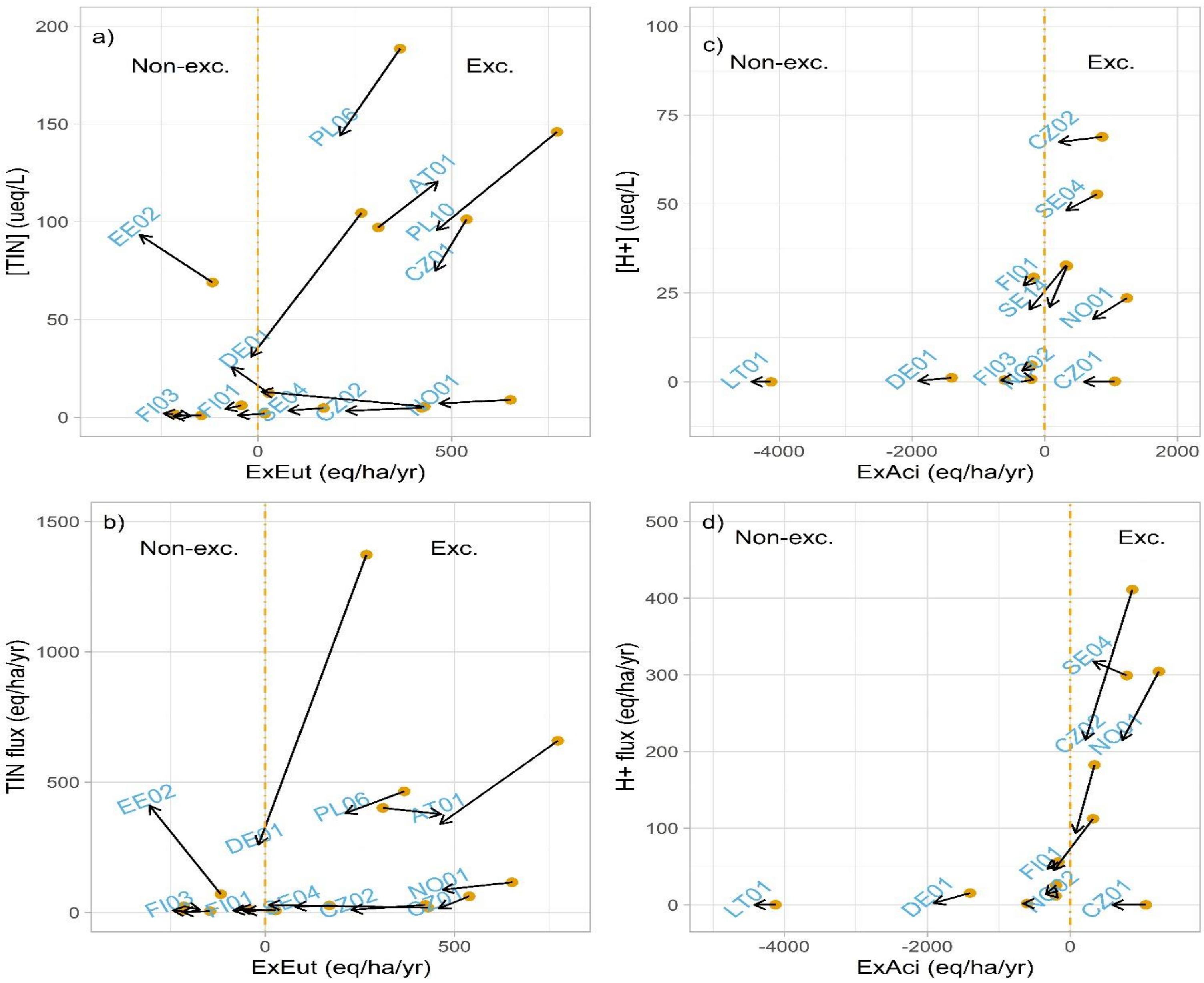
Exceedance of eutrophication critical loads ($CL_{eut}N$) over time at the 17 ICP IM sites using the total N deposition measurements at the sites



Forsius et al. 2020

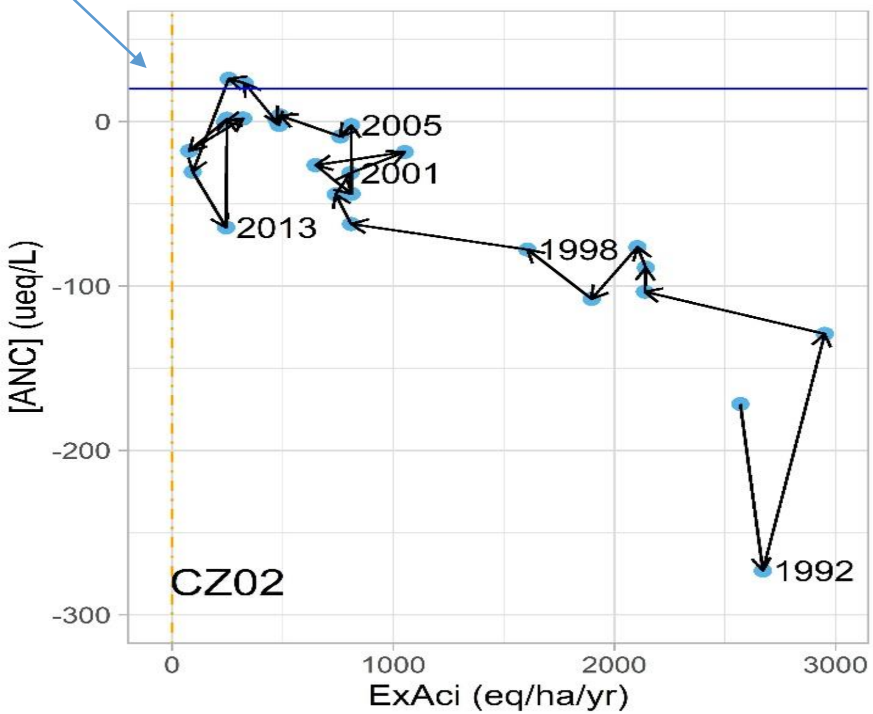
Relations between CL exceedances and runoff water quality

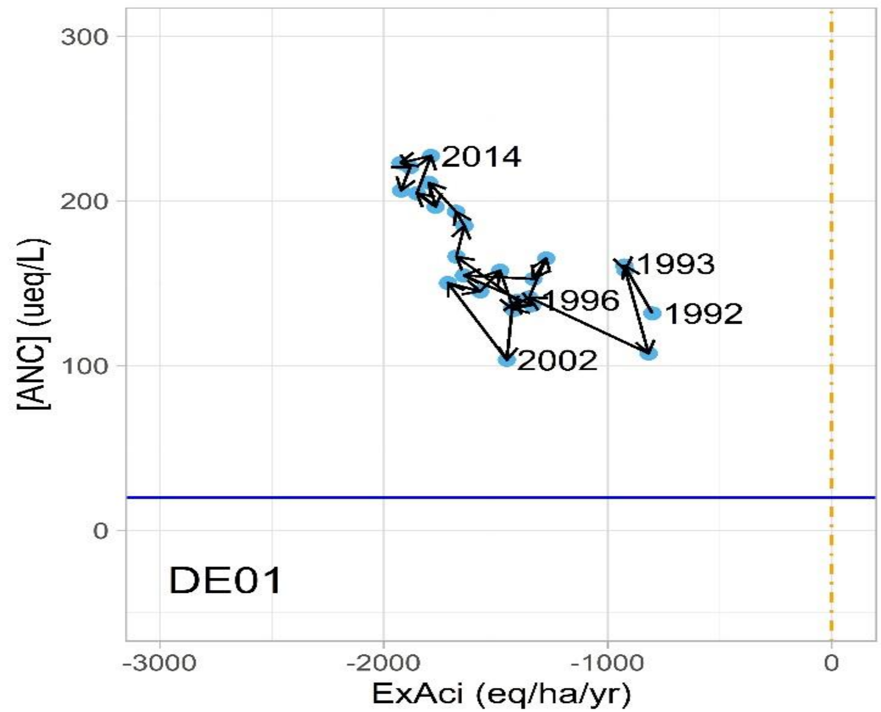


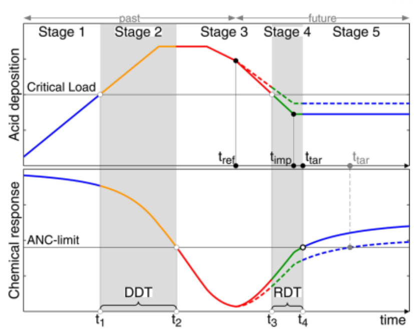
Forsius et al. 2020

Response trajectories for sites CZ02 Lysina and DE01 Forellenbach to the exceedance of the acidity critical load (Recovery Delay Time (RTD) concept)

Critical concentration







Posch et al. 2019

Forsius et al. 2020

Key messages for this question:

- The temporal developments of the exceedance of the CLs indicated the more effective reductions of S deposition compared to N at the sites.
- There was a relation between calculated exceedance of the CLs and measured runoff water concentrations and fluxes, and most sites with earlier higher CL exceedances showed larger decreases in both total inorganic nitrogen (TIN) and H^+ concentrations and fluxes.
- Sites with higher cumulative exceedance of eutrophication CLs (averaged over 3 and 30 years) generally showed higher TIN concentrations in runoff.
- The results confirm that emission abatement actions are having their intended effects on CL exceedances and ecosystem impacts.
- The results also provided evidence on the link between CL exceedances and empirical impacts, increasing confidence in the methodology used for the European-scale CL calculations.

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Question

2.2.c. What is the annual change (or change every 5 years) in water, soil and ecosystem quality indicators between 1990 and 2018/2019? What are projected changes up to 2030 and beyond?

Key references used to derive answer:

- Forsius, M., et al. 2020. Assessing critical load exceedances and ecosystem impacts of anthropogenic nitrogen and sulphur deposition at unmanaged forested catchments in Europe. *Science of The Total Environment* 753: 141791. https://doi.org/10.1016/j.scitotenv.2020.141791
- Vuorenmaa, J. et al. 2018. Long-term changes (1990–2015) in the atmospheric deposition and runoff water chemistry of sulphate, inorganic nitrogen and acidity for forested catchments in Europe in relation to changes in emissions and hydrometeorological conditions. *Science of the Total Environment* 625: 1129–1145. https://doi.org/10.1016/j.scitotenv.2017.12.245
- Vuorenmaa, J. et al. 2020. Long-term changes in the inorganic nitrogen output in European ICP Integrated Monitoring catchments – an assessment of the impact of internal nitrogen-related parameters and exceedances of critical loads of eutrophication, in Kleemola and Forsius, eds., 29th Annual Report 2020:s. *Reports of the Finnish Environment Institute*, pp. 35–45.
- Dirnböck, T. et al. 2018. Currently legislated decreases in nitrogen deposition will yield only limited plant species recovery in European forests. *Environmental Research Letters* 13 (2018) 125010. https://doi.org/10.1088/1748-9326/aaf26b

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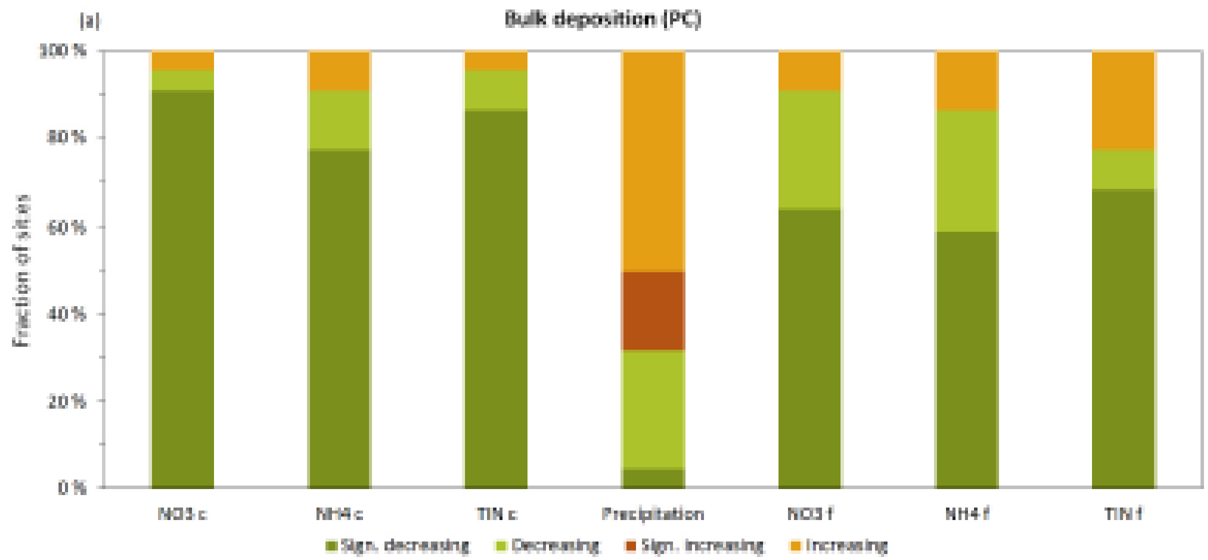
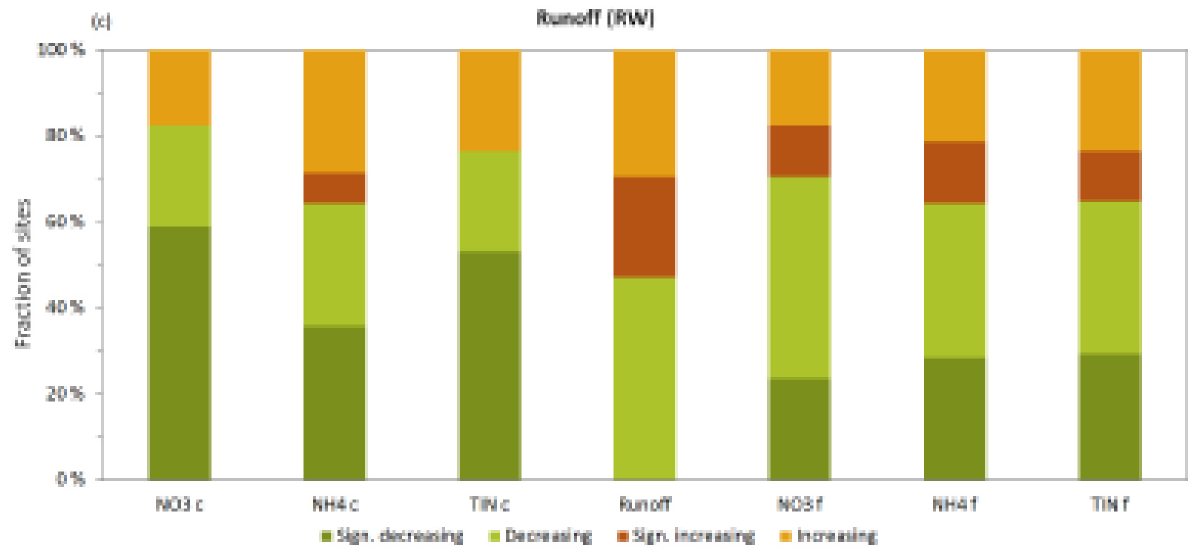
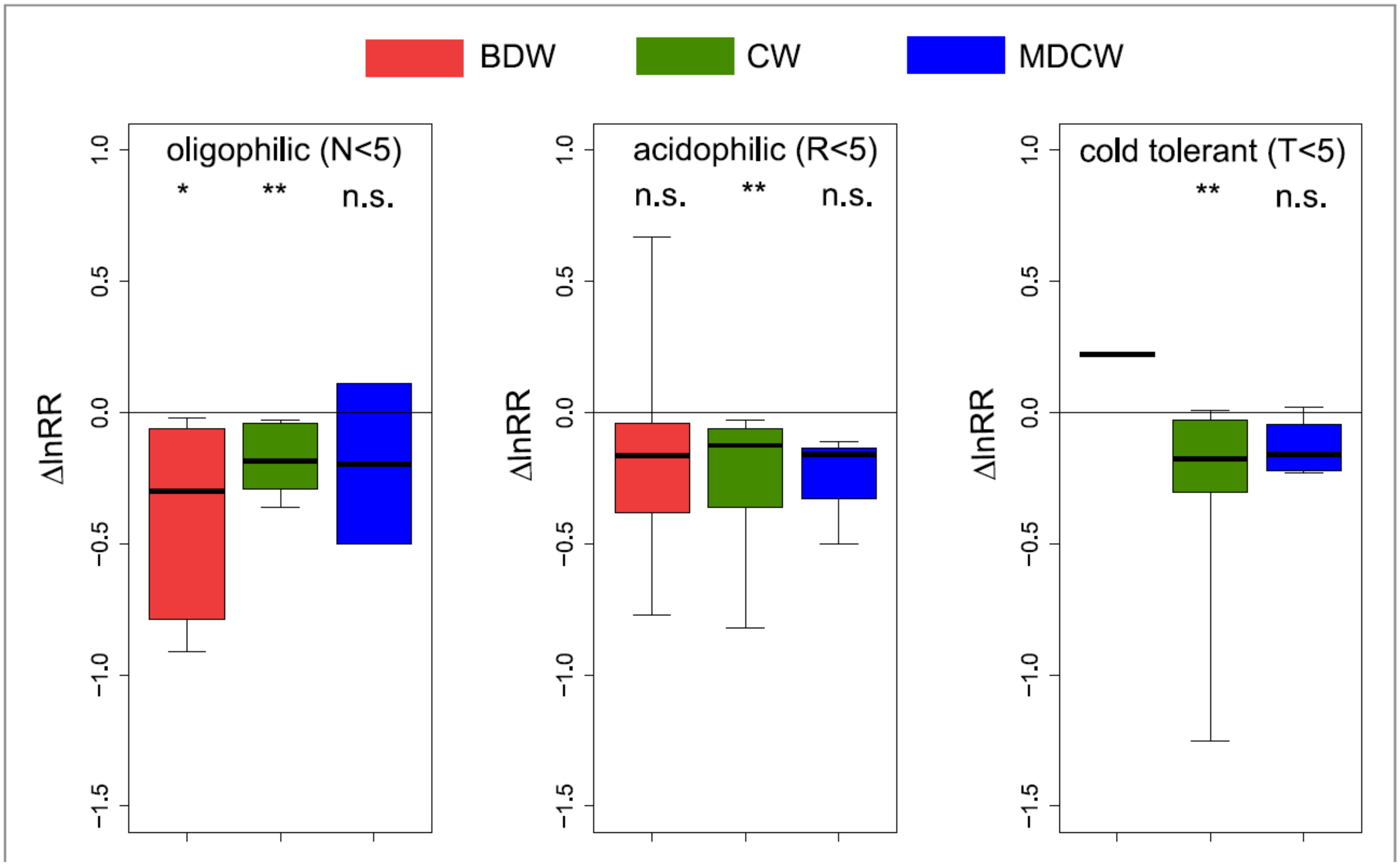
Deposition and water quality trends at ICP Integrated Monitoring catchments





Vuorenmaa et al. 2020

Effects of CLE scenario on on trends in oligophilic, acidophilic , and cold tolerant plant species until 2030



Dirnböck et al. 2018

Key messages (1)

Statistical trend assessments:

- Results of the ICP IM monitoring network confirm the positive effects of the continuing emission reductions
- ICP IM sites showed dominantly negative trend slopes of total inorganic nitrogen (TIN) in concentrations (95% of the sites; mean slope -1.08 µeq L^{-1} yr^{-1}) and fluxes (91% of sites, mean slope -0.84 meq m^{-2} yr^{-1}) of bulk/wet deposition between years 1990 and 2017
- Concentrations of TIN in runoff water for years 1990-2017 exhibited dominantly downward trend slopes (76% of sites, mean slope -0.48 µeq L^{-1} yr^{-1}), and for fluxes 69% of the sites (mean slope -0.21 meq m^{-2} yr^{-1}), respectively. Decrease of NO_3 and NH_4 in concentrations was significant at 59% (-0.36 µeq L^{-1} yr^{-1}) and 36% (-0.05 µeq L^{-1} yr^{-1}) of the sites, and but the decrease in fluxes was significant only at 25% (-0.18 meq m^{-2} yr^{-1}) and 31% (-0.04 meq m^{-2} yr^{-1}) of the sites, respectively.
- Decreasing trends for S and N emissions and deposition reduction responses in runoff water chemistry tended to be more gradual since the early 2000s.

Key messages (2)

Dynamic modelling:

- Dynamic models are needed in order to assess the times scale of impacts and recovery from changes in air pollutant emissions. Interaction with changes in climate variables is also of key importance.
- Decreases in N deposition under the current legislation emission scenario (CLE) will most likely be insufficient to allow recovery from eutrophication.
- Model predictions indicated that oligophilic (favouring nutrient-poor conditions) forest understory plant species will further decrease. This result is partially due to confounding processes related to climate effects and to major decreases in S deposition and consequent recovery from soil acidification.
- Emission reductions of oxidized and reduced N compounds need to be considerably greater to allow recovery from chronically high N deposition.

Question

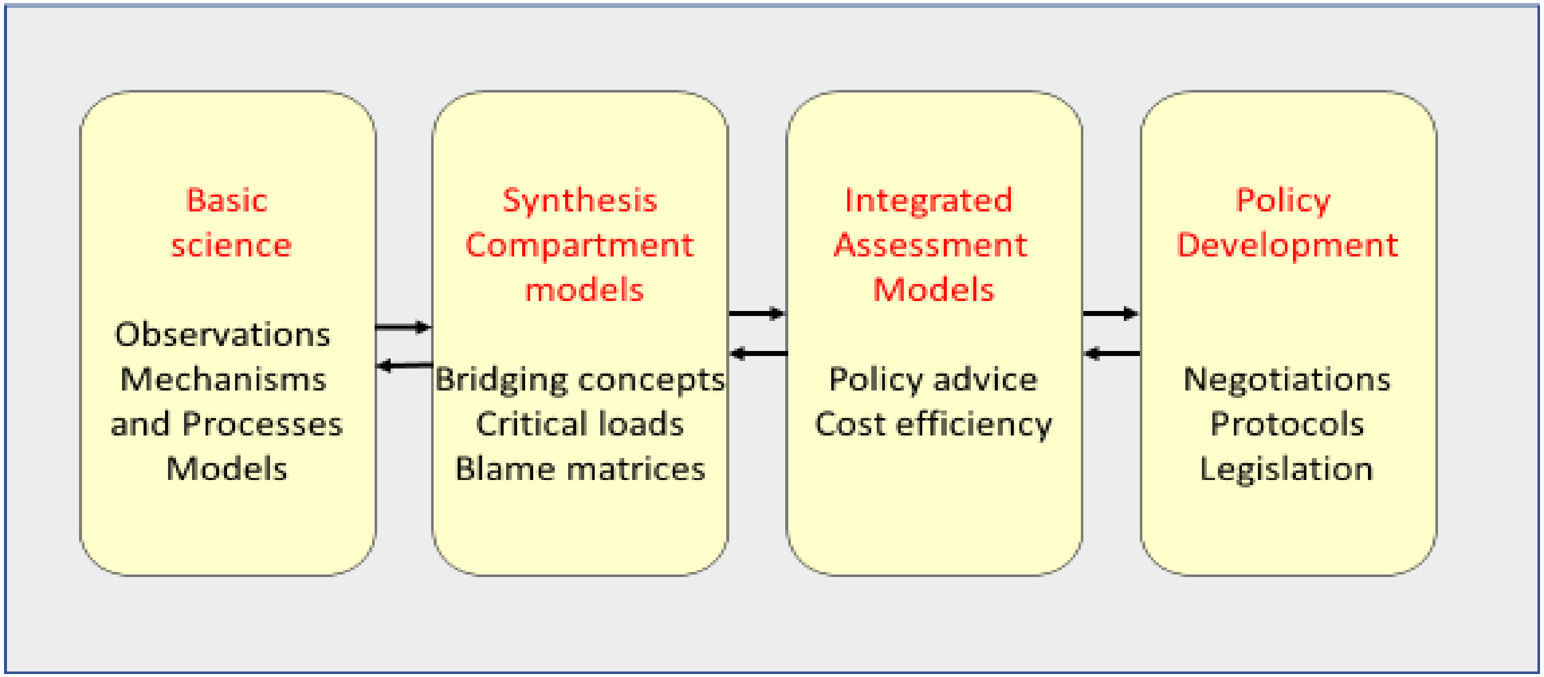
2.7. Is the monitoring and modelling system of the Convention sufficient to observe, assess and project air pollution and its effects related to the Gothenburg Protocol in the ECE region? If no, what are the main challenges and what is needed to meet them?

Key references:

Grennfelt, P., Engleryd, A., Forsius, M., Hov, Ø., Rodhe, H. and Cowling. E. 2020. Acid rain and air pollution– 50 years of progress in environmental science and policy. *Ambio* 49: 849–864. https://doi.org/10.1007/s13280-019-01244-4

Weldon, J. 2018. Post disturbance vegetation succession and resilience in forest ecosystems – a literature review, in Sirpa Kleemola and Martin Forsius, eds., 27th Annual Report 2018, ICP IM, Reports of the Finnish Environment Institute, No. 20 (Helsinki, 2018), pp. 39-52, available at http://hdl.handle.net/10138/238583

Scientific support to regional air pollution policies



Grennfelt et al. 2020, https://doi.org/10.1007/s13280-019-01244-4

Key messages (1)

- Ecosystem effects, which were the main reason for the establishment of the Convention, are to some extent reduced, but the acidification effects of historical emissions will remain for decades and the emissions of ammonia have so far only been reduced by 20–30% in Europe and even less in North America.
- Looking at health effects, it is difficult to talk about success, when hundreds of thousands of inhabitants on both continents are predicted to meet an earlier death due to air pollution.
- The research communities within air pollution and climate change need to work more closely together.
- Basic questions still need further investigations to develop the best policies. Such areas include:
  - a better understanding of health effects from air pollution
  - nitrogen effects to ecosystems
  - air pollution interactions with climate through carbon storage in ecosystems and impacts on radiation balances

Key messages (2)

- A combination of long-term monitoring and research is needed to document and understand complex interactions of air pollutants, climate change and other disturbances.
- Disturbance interactions can have unpredictable and surprising consequences which are as yet insufficiently studied,
- There is a need to extend the current ecosystem monitoring system to include more sites representing other sensitive habitats such as heathlands, grasslands and wetlands. The “IM light” initiative of ICP IM is an important process in this respect.
- Increased cooperation with developing research infrastructures under the EU, such as eLTER, ICOS and ACTRIS would provide possibilities to extend the site networks and increase scientific competence.
- Coordination with ecosystem monitoring efforts of the EU National Emission Ceilings Directive (NEC) would provide similar benefits.

Question

2.8. What are the expected impacts of new scientific findings on environmental and health effects assessments, for example on:

- critical loads,
- critical levels of ozone, particulate matter, nitrogen dioxide and ammonia
- dynamic modelling of ecosystem recovery,
- inclusion of marine ecosystems protection,
- interactions between air pollution, climate change, nitrogen fluxes and other stress factors for biodiversity (e.g. land use changes),
- additional or new metrics on health, damage to crops, ecosystems and/or materials?

Key references:

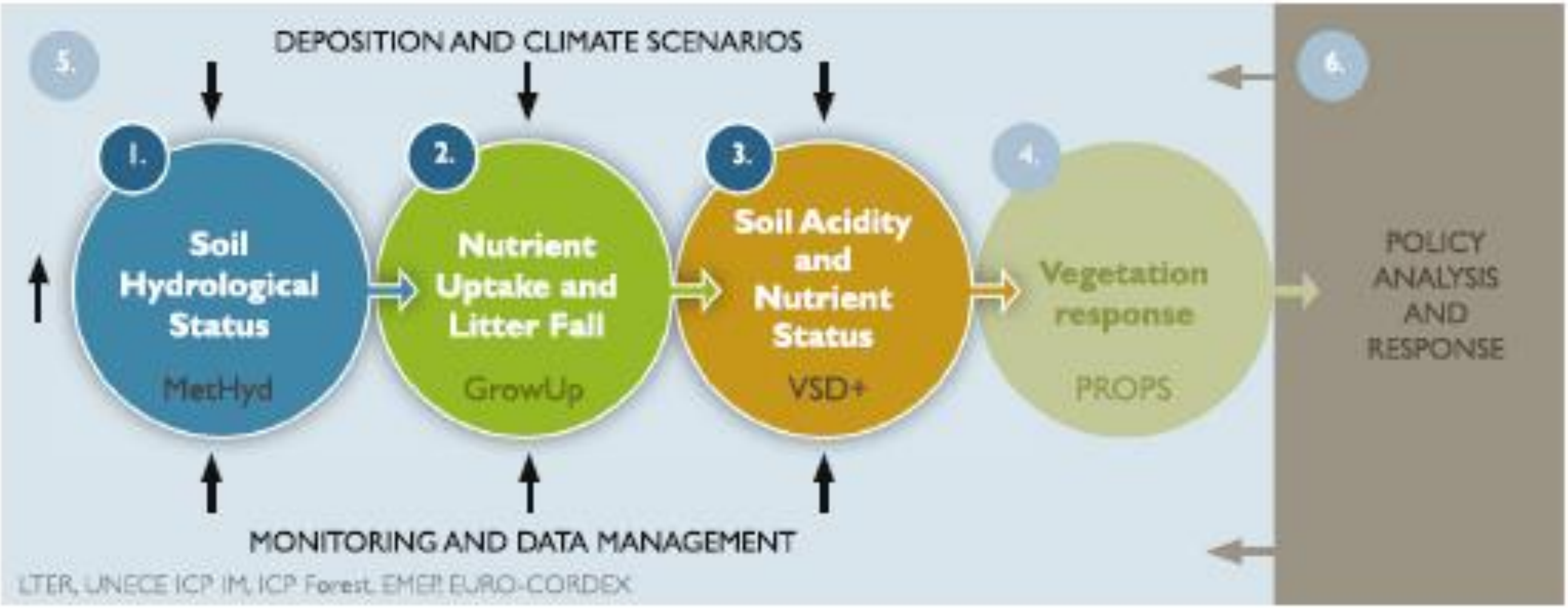
Dirnböck, T. 2018. Currently legislated decreases in nitrogen deposition will yield only limited plant species recovery in European forests. *Environmental Research Letters* 13 (2018) 125010. https://doi.org/10.1088/1748-9326/aaf26b

Holmberg, M. et al. 2018. Modelling study of soil C, N and pH response to air pollution and climate change using European LTER site observations. *Science of the Total Environment* 640–641: 387–399. https://doi.org/10.1016/j.scitotenv.2018.05.299

Posch, M. et al. 2019. Dynamic modeling and target loads of sulfur and nitrogen for surface waters in Finland, Norway, Sweden, and the United Kingdom. *Environmental Science & Technology* 53(9): 5062-5070. https://doi.org/10.1021/acs.est.8b06356

Weldon, J. and Grandin, U. 2021. Weak recovery of epiphytic lichen communities in Sweden over 20 years of rapid air pollution decline. *The Lichenologist* 53: 203-213. https://doi.org/10.1017/S0024282921000037

Dynamic model chain used



Holmberg et al. 2018
Dirnböck et al. 2018

Key messages

- Simulated future soil conditions improved under projected decrease in deposition and current climate conditions: higher pH, base saturation and C:N at 21, 16 and 12 of the 26 simulated sites, respectively.
- When climate change projections were included, soil pH increased in most cases, while BS and C:N increased in about half of the cases. Hardly any climate warming scenarios led to decrease in pH.
- Additional reductions in N emissions are needed to allow recovery of forest understory vegetation from eutrophication.
- Epiphytic lichens which are known to be good indicators of air quality, are of limited indicative ability of recovery after large scale disturbances such as air pollution.
- The advantage of target loads over critical loads is that one can define the deposition and the point in time when the critical limit is no longer violated.
- The target load calculations (Posch et al. 2019) suggested that reductions beyond the Gothenburg Protocol are required to ensure surface water recovery from acidification by 2050.