Economic and Social Council

Distr.: General
4 July 2013

Original: English

Economic Commission for Europe

Executive Body for the Convention on Long-range Transboundary Air Pollution

Working Group on Effects

Thirty-second session
Geneva, 12 and 13 September 2013
Item 4 of the provisional agenda
Recent results and updating of scientific and technical knowledge

Benefits of air pollution control for biodiversity and ecosystem services

Prepared by the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops[1]

Summary

The present summary report was drafted in response to the request of the Executive Body for the Convention on Long-range Transboundary Air Pollution, as set out in the 2012–2013 workplan for the Implementation of the Convention (ECE/EB.AIR/109/Add.2, item 3.1, ongoing activities, para. (d) (iv)). It provides an analysis of how air pollution abatement benefits biodiversity and ecosystem services of benefit to human well-being. Some examples are provided to highlight the indirect benefits of air pollution control for human health and well-being via benefits for ecosystems. A more detailed assessment is available in the full report (informal document No. 1).

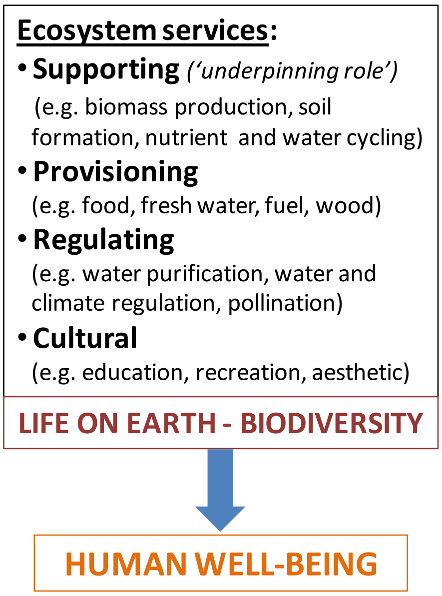
[1] On behalf also of the International Cooperative Programme (ICP) on Modelling and Mapping of Critical Loads and Levels and Air Pollution Effects, Risks and Trends, the ICP on Assessment and Monitoring of Air Pollution Effects on Forests, the ICP on Integrated Monitoring of Air Pollution Effects on Ecosystems, the ICP on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes and the Joint Expert Group on Dynamic Modelling.

Contents

I. Introduction

1. The Earth's ecosystems provide an array of services upon which humans depend for food, fresh water, timber production, disease management, air and climate regulation, aesthetic enjoyment and spiritual fulfilment. Such "ecosystem services" are currently grouped according to the benefits they provide to humans, distinguishing between provisioning, regulating, supporting and cultural services (figure 1). The role of biodiversity in ecosystem services is often rather unclearly stated — biodiversity is sometimes considered as a separate service and yet is implicit in most ecosystem services. Many recent studies have shown the importance of biodiversity for ecosystem services. For example, biodiversity enhances the ability of ecosystems to maintain multiple functions, species richness has positive impacts on ecosystem services, biodiversity decreases the occurrence of diseases, and increased biodiversity enhances pollination and provides an opportunity to increase agricultural yields while also benefitting wildlife.

Figure 1
Ecosystem services are the benefits that people obtain from ecosystems



Source: Adapted from the Millennium Ecosystem Assessment (http://www.millenniumassessment.org).

2. Although humans are an integral part of ecosystems, the burgeoning global population along with increased standards of living and other sociopolitical, economic, technological and societal changes, mean that human interventions can have profound negative effects on the quality of the services provided by ecosystems, hence affecting human well-being. The indirect benefits of air pollution control for human health and well-being via a reduction in the impacts on ecosystem services and biodiversity are often not included in (economic) valuations. At a global level, it is estimated that nearly two thirds of ecosystem services have been degraded in just 50 years. For that reason, the Intergovernmental Platform on Biodiversity and Ecosystem Services was established in 2012. Additional stresses imposed by, for example, climate change will require extraordinary adaptation efforts. In this report, an assessment of the state of current knowledge on the effects of air pollution on biodiversity and ecosystem services is provided.

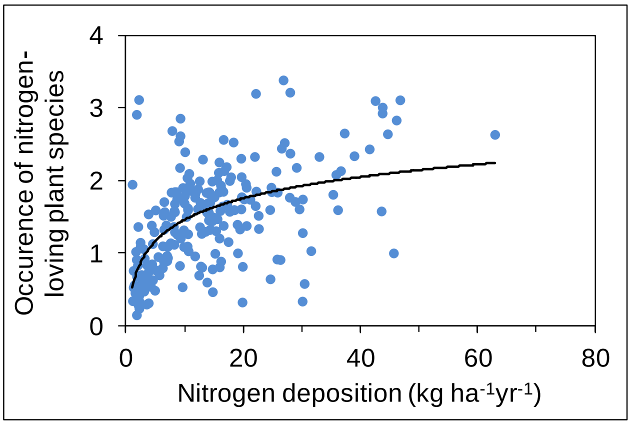
II. Benefits for biodiversity

A. Enhanced atmospheric nitrogen deposition poses a threat to plant diversity

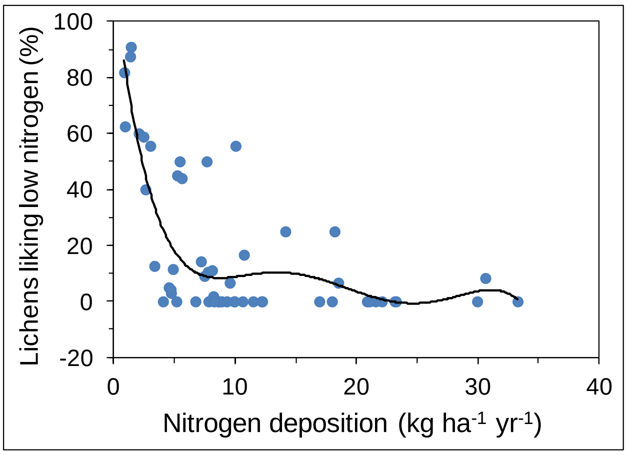
3. It is well known that increased atmospheric nitrogen deposition stimulates the presence of nitrogen-loving plant species but reduces the occurrence of plant species adapted to low nitrogen availability (figure 2 (a); see also ECE/EB.AIR/WG.1/2007/15, ECE/EB.AIR/WG.1/2009/15 and ECE/EB.AIR/WG.1/2010/14). Some lower plant species such as lichens and mosses are particularly sensitive to excessive nitrogen and sensitive species will disappear in areas with elevated nitrogen deposition (figure 2 (b); see also ECE/EB.AIR/WG.5/2007/3). For example, the proportion of lichens preferring low nitrogen conditions decreased on average below 40 per cent when the nitrogen deposition below the forest canopy exceeded 3.8 kilograms (kg) per hectare (ha^-1) per year (yr^{-1}). In addition, enhanced nitrogen deposition decreases the resilience of ecosystems to other environmental stresses such as drought, high wind, frost, pest and diseases.

Figure 2

(a) Effect of atmospheric nitrogen deposition on the occurrence of nitrogen-loving plant species



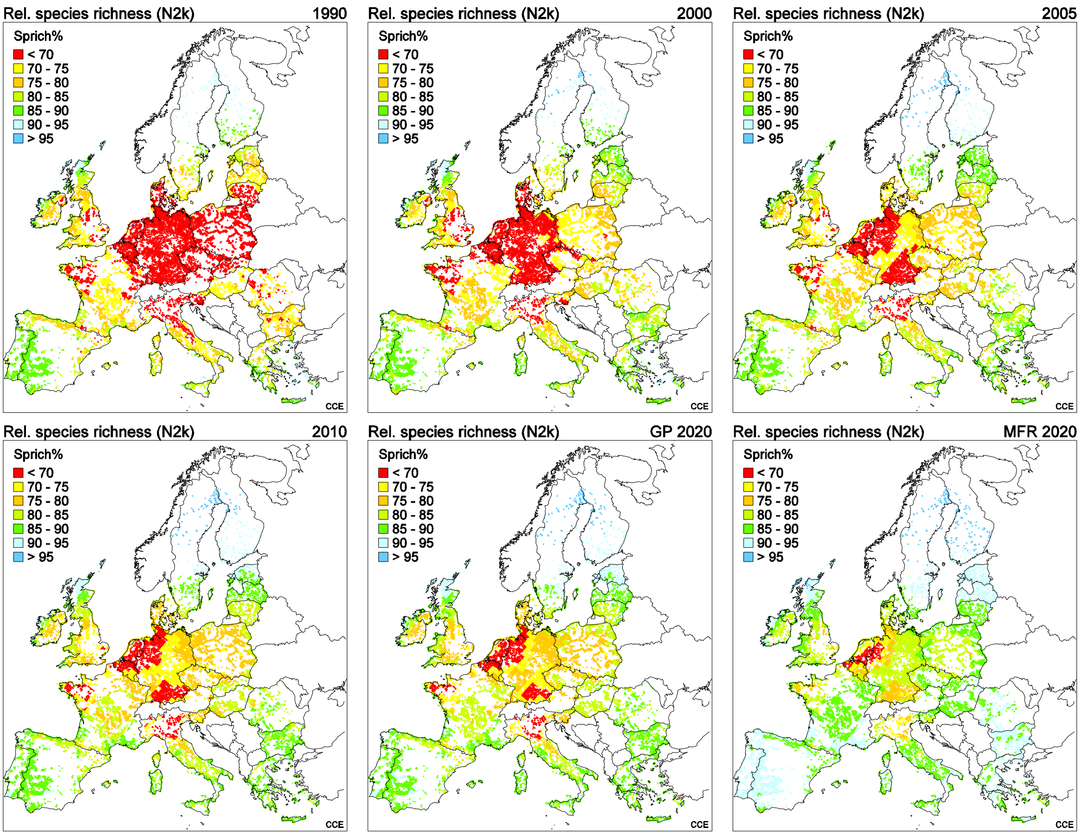
(b) Effect of atmospheric nitrogen deposition on the proportion of lichens adapted to low nitrogen availability in forests



4. In a first analysis to assess the impacts of the revised Protocol to Abate, Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol)[2] on plant species richness in Natura 2000 grasslands, a dose-response relationship established for acid grasslands across Europe was applied, with the total atmospheric nitrogen (N) deposition ranging from 2.4 to 43.5 kg N ha^{-1} yr^{-1}. The relative grassland species richness was estimated using depositions on Natura 2000[3] areas since 1980 computed with the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) model[4] on a 50 square kilometre (km^2) x 50 km^2 grid (figure 3). The average species richness in Natura 2000 grasslands (European Nature Information System (EUNIS)[5] classes E1, E2, E3) was estimated to be 72 per cent in 1990, 78 per cent in 2005 and 81 per cent in 2020 under the revised Gothenburg Protocol. Although this example suggests that the impact of atmospheric nitrogen deposition on plant species diversity is expected to decline in the future, there still will be a net loss of plant diversity, even under the maximum feasible reduction (MFR) scenario.

Figure 3

Relative plant species richness in EUNIS classes E1, E2 and E3 grasslands in 1990, 2000, 2005, 2010 and 2020 under the revised Gothenburg Protocol and in a maximum feasible reduction scenario



5. The above assessments should be extended to other ecosystems and biodiversity indicators (e.g., presence of species threatened with extinction, soil organisms) for a

[2] Available from http://www.unece.org/env/lrtap/multi_h1.html.

[3] See http://ec.europa.eu/environment/nature/natura2000/.

[4] See https://wiki.met.no/emep/page1/emepmscw_opensource.

[5] See http://eunis.eea.europa.eu/about.jsp.

comprehensive analysis of the impacts of excessive nitrogen deposition on biodiversity. It should also be noted that effects of excessive nitrogen deposition on the structure and functioning of ecosystems and its biodiversity may not occur instantly, it may take several decades over which the resilience of soils and vegetation is weakened and impacts become apparent. In addition, little is known about the recovery from historic nitrogen pollution, which is unlikely to follow the same dose-response relationship.

B. Impacts of ozone on plant diversity

6. Typical effects of ozone on sensitive plant species include: accelerated aging; reduction in biomass; and changes in resource allocation and/or seed production. Each of these effects can impact on the vitality of component species of plant communities, potentially altering species balance and plant diversity (see ECE/EB.AIR/WG.1/2007/9), as well as that of the animals, fungi, bacteria and insects that live in close association with plants or in nearby soils. In so doing, ozone-induced changes in species diversity or shifts in species balance will impact on many ecological processes, thereby impacting on ecosystem services, flows, goods and values. Effects on species balance have been widely reported from controlled exposure experiments, but a less clear picture emerges from field-based studies with long established communities and from field surveys. The first results from field surveys in the United Kingdom of Great Britain and Northern Ireland suggest that the impact of ozone on plant species richness is habitat dependent. Although more studies are needed, it is clear that impacts of ozone are of particular concern for global biodiversity hotspots such as the Mediterranean basin.

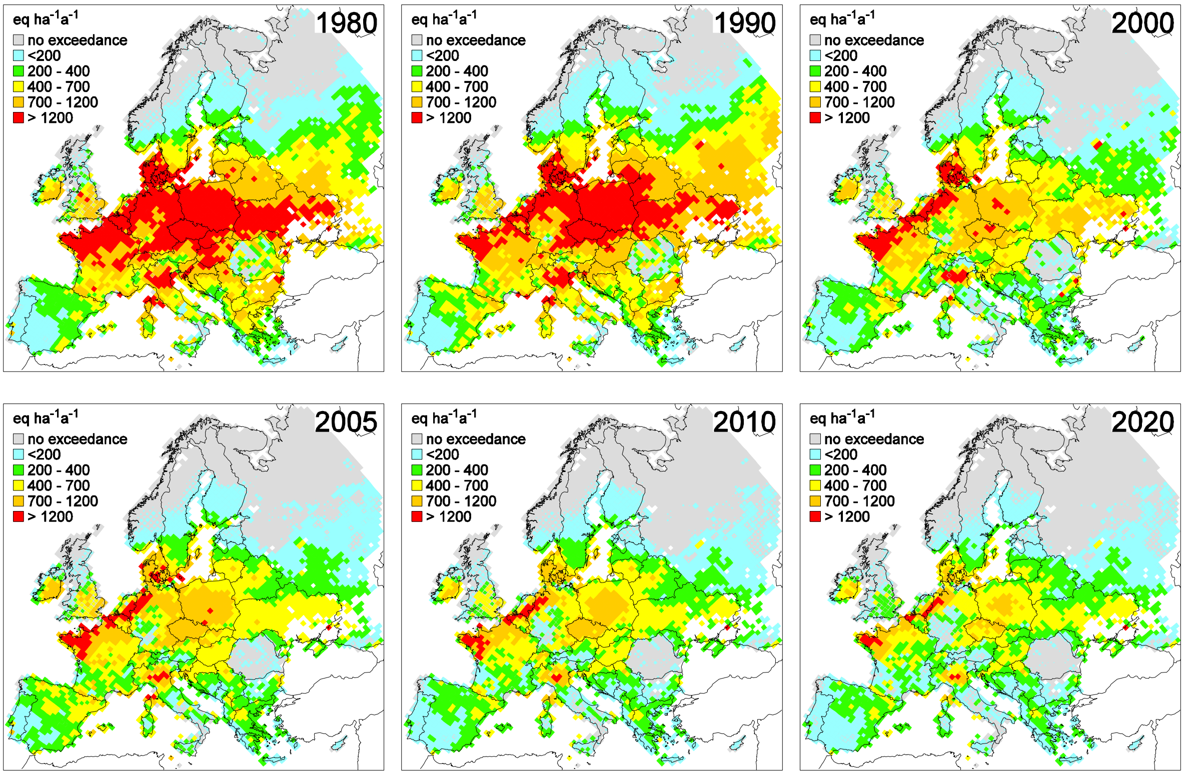
III. Benefits for ecosystem services

A. Benefits of further nitrogen pollution abatement measures

7. Generally, nitrogen deposition in excess of critical loads causes adverse effects on the structure and functioning of ecosystems, which may take several years to decades to become apparent. Emission projections based on the revised Gothenburg Protocol show that the area at risk will diminish from 73 per cent in 1990, to 51 per cent in 2005 to 42 per cent in 2020 (figure 4). This means that many areas will still be at risk in 2020, particularly in Central Europe, and additional air pollution abatement measures are required to further reduce the risk of nitrogen critical load exceedance in 2020 and beyond.

Figure 4

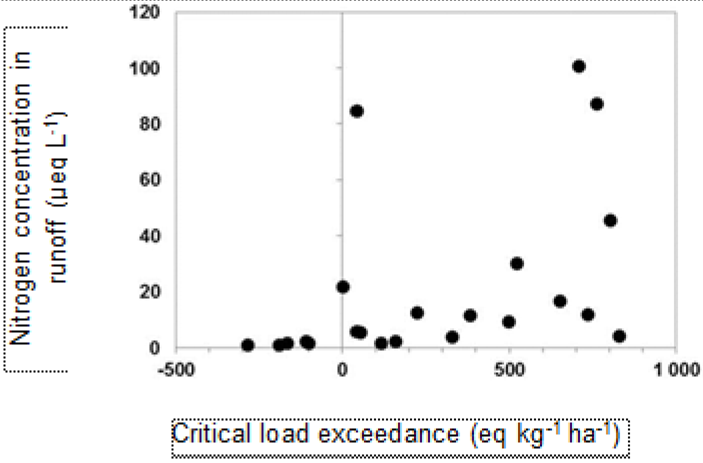
Areas where critical loads for eutrophication are exceeded by nutrient nitrogen depositions caused by emissions between 1980 and 2020, the last projected under the revised Gothenburg Protocol



8. Soils store air pollutants temporarily and therefore play an important role in keeping surface and drinking water clean. However, the stored pollutants will adversely affect soil functioning (e.g., microbes and invertebrates) and create problems when the retention capacity is reached or disturbed, and pollutants start leaching to surface and drinking water and coastal zones. Nitrogen leaches from soils above the critical threshold, i.e., at a critical load exceedance of zero (figure 5). Nitrogen leaches from forest soil at a carbon to nitrogen ratio below 23 in the organic layer. Nitrogen concentrations in the soil solution exceeding the critical limit for nitrogen leaching have been observed in two thirds of monitored forest plots, posing a threat of nitrate concentrations in groundwater beyond the threshold for drinking water quality. Excessive nitrogen input in lakes and coastal zones will stimulate algal growth.

Figure 5

Exceedance of empirical critical load of nitrogen in soils results in enhanced inorganic nitrogen concentrations in run-off



9. In areas with a high nitrogen deposition load, the organic matter and nutrient cycling in soils is most likely disturbed and forest health and vitality may be at risk. These areas are mainly situated in West-Central Europe, in parts of East-Central Europe, and in the Baltic States. Forest growth is stimulated by elevated nitrogen deposition in areas where nitrogen availability is limiting forest growth, potentially resulting in a stimulation of carbon sequestration in the living biomass of trees. However, if the forest soil cannot supply other nutrients (especially base cations like calcium and magnesium) in a balanced and sustainable way, impaired tree health is likely to occur.

B. Benefits of reduction of ground-level ozone for food security, carbon sequestration and other ecosystem services

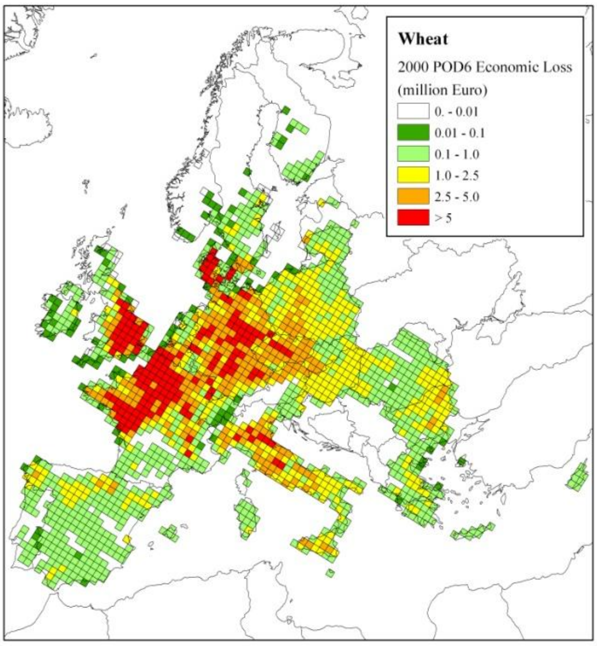
10. Globally important staple food crops are among the most ozone sensitive, including wheat, soybeans and rice. Other important European crops such as potatoes, sugar beets and oilseed rape are moderately sensitive to ozone (see ECE/EB.AIR/WG.1/2011/3 and ECE/EB.AIR/WG.1/2011/8). In addition, ozone damages the leaves of salad crops, reducing their market value (or even making them unmarketable after a severe ozone episode). Economic losses due to ozone effects on wheat and tomato yield were estimated to be €3.20 and €1.07 billion respectively in the 27 member states of the European Union plus Norway and Switzerland in 2000. Wheat yield losses due to ozone were highest in Western and Central Europe, where high ozone uptake by vegetation coincided with large areas of wheat cultivation (figure 6 (a)). Implementation of current legislation will reduce yield losses due to ozone by 2020; however, substantial reductions in ozone precursor emissions would be needed to achieve zero crop losses.

11. Ozone is also the third most important greenhouse gas. Negative impacts on vegetation reduce the sink capacity for carbon dioxide and ozone, enhancing their atmospheric concentration (positive feedback), while also affecting the global water cycle. The indirect stimulating contribution of ozone to global warming via ozone effects on vegetation can be as important as the direct effect of ozone as a greenhouse gas. Hence, it is important to include the impacts of ozone on vegetation in global climate change models. In 2000, ambient ground-level ozone was estimated to reduce carbon sequestration in the living biomass of trees by 12 to 14 per cent (see ECE/EB.AIR/WG.1/2012/3 and ECE/EB.AIR/WG.1/2012/8). The forested areas with the highest reductions in carbon

sequestration were Central Europe and parts of Northern Europe, with total effects per grid square dependent on the density and age class of ozone-sensitive species as well as accumulated ozone flux (figure 6 (b)).

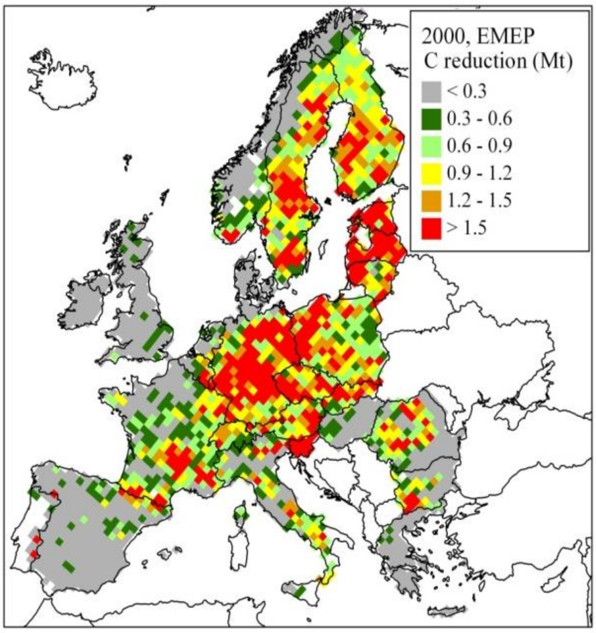
Figure 6

(a) Wheat yield losses due to ozone



Abbreviation: POD_6 = phototoxic ozone dose expressed as the accumulated flux of ozone above a flux threshold of 6 nmol m^{-2} projected leaf area s^{-1}.

(b) Estimated reduction in carbon sequestration in the living tree biomass due to ozone in Europe in 2000



Abbreviation: C = carbon; Mt = megatons.

12. Reported ozone-induced changes in the quantity of flowers and timing of flowering will play an important role in the reproductive success of plants, particularly for species in which flowering is closely synchronized with pollinating species. A recent meta-analysis of ozone effects on plant reproductive growth and development indicated that current ambient ozone concentrations significantly reduce seed number (16 per cent), fruit number (9 per cent) and fruit weight (22 per cent), while there was a trend towards increasing flower number and weight. Floral scent trails, important in pollinator attraction and plant defences against herbivorous insects, have also been shown to be destroyed or transformed by ozone. These ozone-induced changes in flowering timing and signaling could have major ecological impacts.

13. Ground-level ozone will also affect other ecosystem services such as carbon, nutrient and water cycling, timber production and methane emission (see ECE/EB.AIR/WG.1/2013/8 for further details).

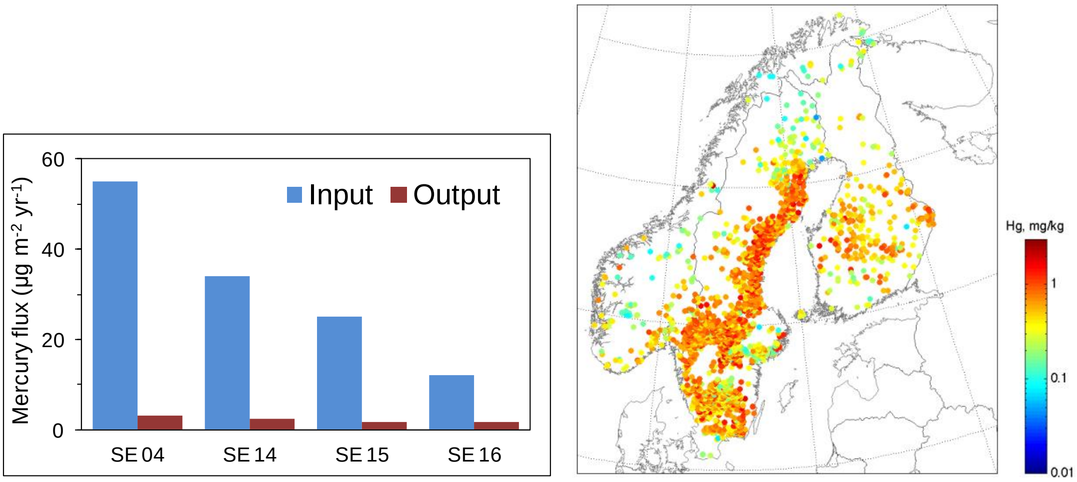
C. Benefits of reduction of mercury emissions

14. Heavy metals such as mercury accumulate in soils (figure 7 (a)), affecting soil functioning and potentially creating severe problems in the future when the retention capacity of the soil is reached or disturbed and high concentrations start leaching to surface and drinking water and coastal zones. Mercury is also accumulating through the food chain; for example, in over half the lakes in Sweden the mercury level in fish is higher than the recommended value for human consumption (figure 7 (b)). Recent studies have predicted that the mercury level in fish might rise in a future warmer climate.

Figure 7

(a) Mercury fluxes in soils at four sites in Sweden

(b) Mercury concentrations in pike in lakes in Fennoscandia



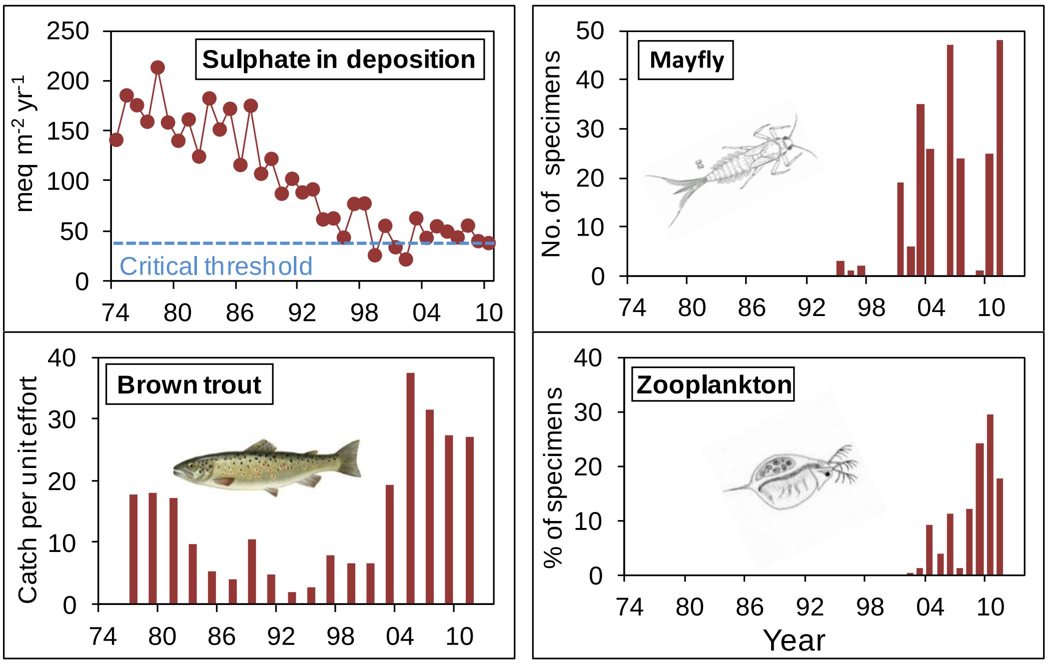
Note: The recommended mercury concentration in pike for human consumption is 1 milligram (mg) kg^{-1}.

D. Success story: biological recovery from acidification is finally happening

15. Acidification of soils from both sulphur and nitrogen deposition negatively affects the nutrient balance in soils required for healthy plant growth and productivity. However, the threat of acidification has been reduced in recent decades due to the reduction in sulphur

deposition, including as a consequence of the implementation of stringent sulphur emission abatement policies within the Convention. There has been a delay in chemical recovery from acidification in lakes in Northern Europe and an even longer delay in biological recovery, with implications for biodiversity and tourism. For example, recreational fishing has long been impaired in regions with acidified surface waters, which has had a major adverse impact. Biological recovery has started in the last decade (e.g., figure 8), which in some areas has been aided by the application of liming.

Figure 8
Biological recovery from acidification in Lake Saudlandsvatn, a typical (non-limed) lake in southern Norway



IV. Conclusions

16. Based on the current review, the following conclusions were drawn:

(a) Awareness of ecosystem services, including biodiversity, in both monetary and non-monetary terms helps to assess the real benefits of air pollution control;

(b) It is very encouraging that there are signs of chemical and biological recovery from acidification. It remains uncertain whether full recovery of biodiversity from adverse effects of historic air pollution will be possible;

(c) Further air pollution abatement will continue to reduce the threat to loss of biodiversity, however, “no net loss of biodiversity” will not be achieved by 2020 under the revised Gothenburg Protocol;

(d) With full implementation of the revised Gothenburg Protocol, further benefits are expected for ecosystem services such as air, soil and water quality and crop production;

(e) Further air pollution abatement policies will enhance the resilience of biodiversity and ecosystem services to climate change.

V. Recommendations

17. Based on the current review, the following recommendations were made:

(a) To halt biodiversity loss and adverse impacts of air pollution on human well-being, policy negotiations should take into account the benefits of air pollution control for ecosystem services in addition to the direct benefits for human health;

(b) More stringent air pollution abatement measures beyond the revised Gothenburg Protocol are required to achieve “no net loss of biodiversity”;

(c) The full benefits of air pollution abatement for ecosystem services (and hence human well-being) have to be assessed and weighed against the costs of more stringent air pollution controls;

(d) The effects-based integrated assessment of policies that address driving forces of environmental issues could be further balanced by including “no net loss of biodiversity and ecosystem services” in air, waters, soils and vegetation as an explicit endpoint.