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Progress in activities in 2014 and further development of effects-oriented activities

Deposition of air pollutants to vegetation in Eastern and South-Eastern Europe, the Caucasus and Central and South-East Asia and their impacts

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

Summary

The present thematic report by the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops 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 2014–2015 workplan for the implementation of the Convention (ECE/EB.AIR/122/Add.2, item 1.1.17 (c)). It provides an analysis of air pollutant deposition to and impacts on vegetation in Eastern and South-Eastern Europe, the Caucasus and Central and South-East Asia. The report highlights the lack of monitoring activities and the major air pollution problems in these regions. Country reports were included for the Russian Federation and various countries in South-Eastern Europe (Albania, Croatia, Greece, Romania, Serbia, Slovenia and the former Yugoslav Republic of Macedonia).

[1] With data contributions from the Coordination Centre for Effects, the Meteorological Synthesizing Centre-West and the Meteorological Synthesizing Centre-East.

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I. Introduction

1. Increased ratification of the protocols to the Convention on Long-range Transboundary Air Pollution was identified as a high priority in the Long-term Strategy for the Convention (ECE/EB.AIR/106/Add.1, decision 2010/18, annex). Increased ratification and full implementation of air pollution abatement policies is particularly desirable for countries of Eastern and South-Eastern Europe, the Caucasus and Central Asia. Hence, scientific activities within the Convention need to involve those countries. In the current report, the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) has reviewed current knowledge on the deposition of air pollutants to and their impacts on vegetation in countries of Eastern Europe, the Caucasus and Central Asia (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan) and South-Eastern European countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Montenegro, Romania, Serbia, Slovenia, the former Yugoslav Republic of Macedonia and Turkey). As an outreach activity to Asia, current knowledge on this subject was also reviewed for the Malé Declaration countries in South-East Asia (Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan and Sri Lanka).[2] Air pollution is the main concern in Asia due to enhanced industrialization, which is directly linked to strong economic growth in recent decades. The report highlights the lack of monitoring activities and the major air pollution problems in these regions.

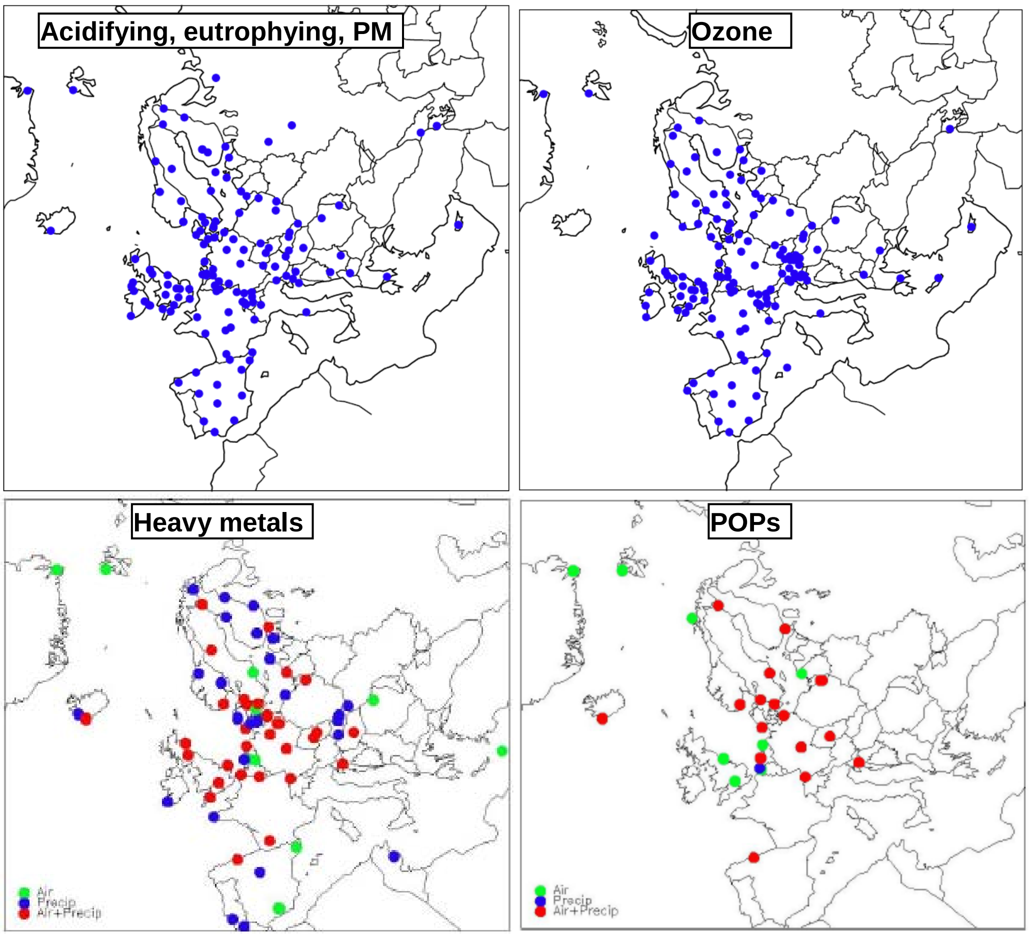
2. In particular, the present report responds to the request of the Executive Body for the Convention, as set out in the 2014–2015 workplan for the implementation of the Convention (ECE/EB.AIR/122/Add.2, item 1.1.17 (c)) for a thematic report on air pollution deposition to and impacts on vegetation in Eastern and South-Eastern Europe, the Caucasus and Central and South-East Asia. In addition to country reports provided by several countries cooperating with ICP (Albania, Croatia, Greece, Romania, Russian Federation, Serbia, Slovenia and the former Yugoslav Republic of Macedonia), it is based on data provided by the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), with data contributions from the Coordination Centre for Effects (CCE), the Meteorological Synthesizing Centre-West (MSC-W) and the Meteorological Synthesizing Centre-East (MSC-E).

3. ICP Vegetation, a subsidiary body to the Convention under the Working Group on Effects, is planned and coordinated by a Task Force led by the United Kingdom and supported by a coordination centre at the Centre for Ecology and Hydrology in Bangor, United Kingdom. Currently 20 Parties to the Convention actively participate in the programme.

[2] See Harry Harmens and Gina Mills, eds., *Air pollution: Deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia* (Bangor, United Kingdom: ICP Vegetation Programme Coordination Centre, Centre for Ecology and Hydrology, 2014). Available from http://icpvegetation.ceh.ac.uk/publications/thematic.html.

Figure 1

The EMEP monitoring network for acidifying, eutrophying compounds and particulate matter, ozone, heavy metals and persistent organic pollutants



Abbreviations: PM = particulate matter; POPs = persistent organic pollutants.

Sources: EMEP/MSC-W and MSC-E.

Notes: Monitoring sites operational in 2011: for acidifying, eutrophying compounds and PM (top left) (excludes ozone-only measurement sites); for ozone (top right); for heavy metals (bottom, left) (note that Cyprus is moved to fit inside the map); and for POPs (bottom, right).

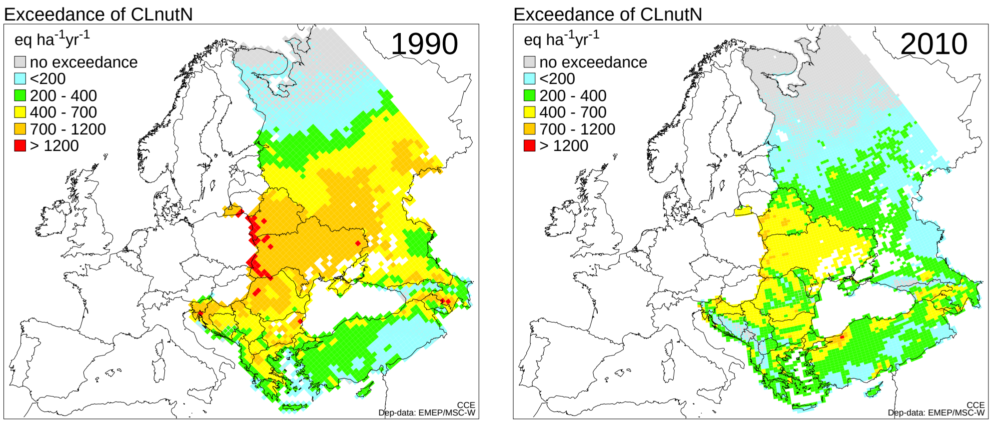
4. In the regions covered, there is generally a lack of an extensive network of monitoring stations to assess the magnitude of air concentrations and depositions of pollutants (figure 1). In addition, emission inventories are often incomplete or not reported at all for some pollutants, which makes it difficult to validate atmospheric transport models for these regions. Furthermore, there is often a lack of coordinated monitoring networks to assess the impacts of air pollution on vegetation. Hence, the risk of adverse impacts on vegetation often has to be assessed using atmospheric transport models in conjunction with metrics developed to compute the risk of air pollution impacts on vegetation, such as critical loads and levels. The report focuses on the air pollutants nitrogen, ozone and heavy metals; persistent organic pollutants (POPs) were only included for countries in Eastern and South-Eastern Europe, the Caucasus and Central Asia, and information on aerosols, including black carbon as a component, was only included for South-East Asia.

II. Nitrogen

5. Critical load exceedances for nutrient nitrogen are only available for a limited number of countries in Eastern Europe, the Caucasus and Central Asia. In Western and Central Europe available computed critical load exceedances for nitrogen have historically been lower than in South-Eastern Europe and large areas of Eastern Europe, the Caucasus and Central Asia, particularly the northern part, and this was also the case in 2010 (figure 2). However, the critical load is expected to still be exceeded in large areas in 2020 with improvements since 2005 generally being lower than in Western and Central Europe, particularly in Eastern Europe, the Caucasus and Central Asia.[3]

Figure 2

Areas in Eastern Europe where critical loads for eutrophication are exceeded by nutrient nitrogen deposition in 1990 (left) and 2010 (right)



Source: CCE.

Note: The 1990 map is on the EMEP 50 kilometre (km) × 50 km grid, whereas the 2010 map is on the 0.5 × 0.25 degree longitude-latitude grid using the latest EMEP model output; the critical loads are from the 2011–2012 database.

6. Nitrogen concentrations in mosses in 2005 and 2010 were only reported in Bulgaria, Croatia, Slovenia, the former Yugoslav Republic of Macedonia and Turkey (2005 only) and were not reported in any of the countries in Eastern Europe, the Caucasus and Central Asia. Nitrogen concentrations in mosses were found to be intermediate to high in South-Eastern Europe as compared with other European countries, indicating potentially a higher risk of nitrogen effects on ecosystems than computed by the critical loads.

III. Ozone

7. For the first time, ICP Vegetation has mapped the risk of adverse impacts of ozone on vegetation for the extended EMEP domain using the flux-based metric POD_Y[4] (figure 3).

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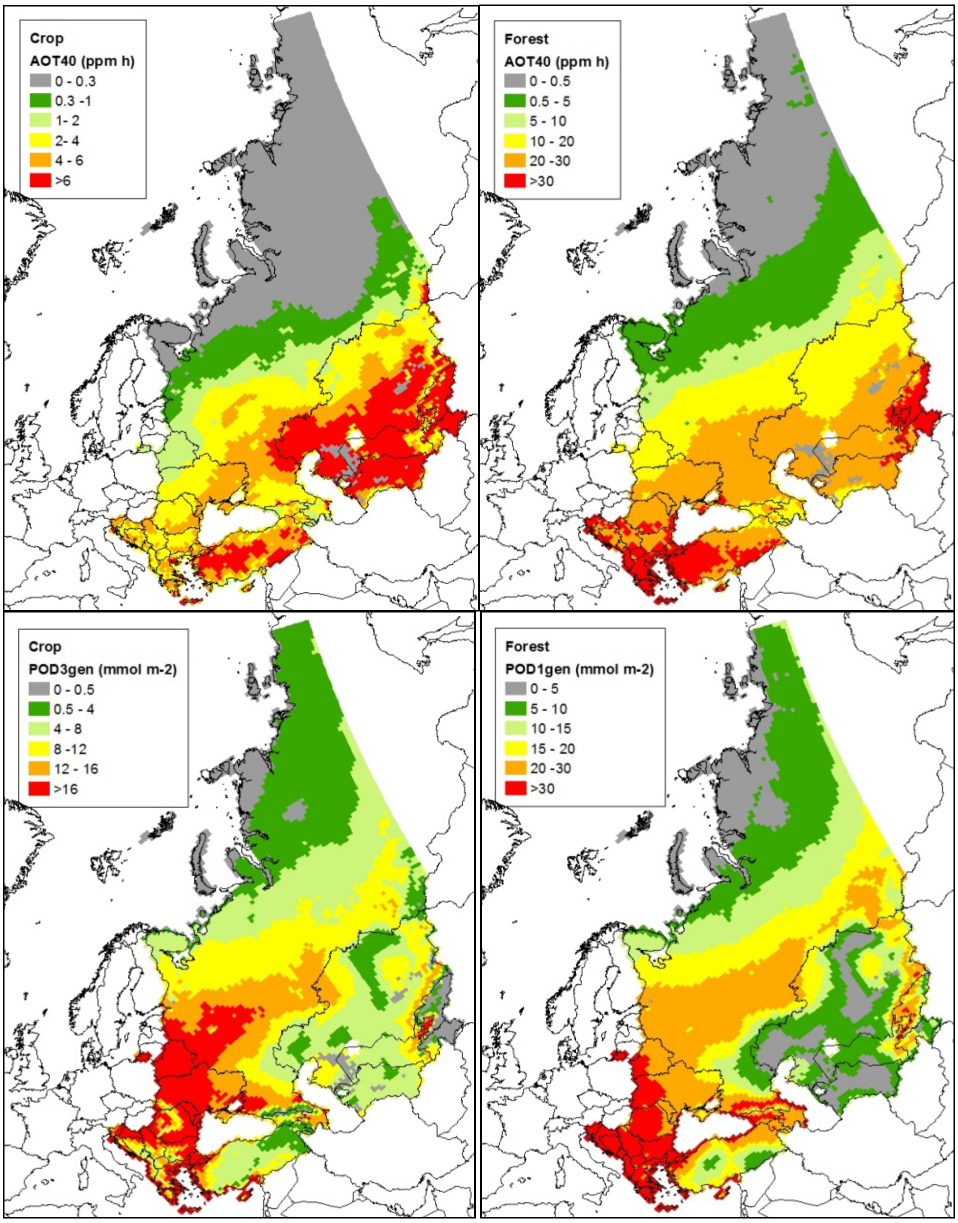
[3] See Jean-Paul Hettelingh and others, “Assessing Effects of the Revised Gothenburg Protocol”, in *Modelling and mapping of atmospherically-induced ecosystem impacts in Europe: CCE Status Report*, M. Posch, J. Slootweg and J.-P. Hettelingh, eds. (Bilthoven, the Netherlands: Coordination Centre for Effects, 2012).

[4] Phytotoxic Ozone Dose above an ozone flux threshold of Y nanomoles per square meter of projected leaf area per second (nmoles m^{-2} s^{-1}).

Figure 3

Indication of the spatial pattern of vegetation at risk of adverse impacts of ozone in countries of Eastern and South-Eastern Europe, the Caucasus and Central Asia, averaged over the period 2007-2011



Notes: Maps are shown for the concentration-based approach (AOT40;[5] top) and the flux-based approach (PODY; bottom). The flux-based risk is shown for a generic crop species (left) and a generic tree species (right) as defined for integrated assessment modelling. Data per the 50 km x 50 km grid were downloaded from the EMEP/MSC-W website. The flux model used to generate the data in this figure provides an estimation of the worst case for damage with adequate water supply (either rain-fed or irrigated). Reductions in ozone flux associated with dry soils such as those found in arid regions are not included in this model and thus effects may be overestimated, for example in areas where crop irrigation is not used.

[5] Accumulated hourly mean Ozone concentration over a Threshold of 40 parts per billion, during daylight hours.

8. The concentration-based approach (AOT40)[6] identifies the southern part of the Eastern Europe, the Caucasus and Central Asia region at highest risk, whereas the biologically more relevant flux-based approach (POD_Y) identifies the South-Western part of the region bordering with Central Europe at highest risk. Both approaches indicate that the northern part of the region is at lowest risk of adverse impacts from ozone pollution. Field-based evidence is available for ozone impacts on crops in Greece and Slovenia, with many crop species showing visible leaf injury in Greece. Both AOT40 and POD_Y were computed to be high in South-Eastern Europe, indicating that this area is at high risk of ozone damage to vegetation.

9. Staple food crops (maize, rice, soybean and wheat) are sensitive to moderately sensitive to ozone, threatening global food production. Recent flux-based risk assessment of ozone-induced wheat yield loss showed that the estimated relative yield loss was 6.4 to 14.9 per cent for China and 8.2 to 22.3 per cent for India in 2000, with higher yield losses predicted for 2020, indicating the urgent need for curbing the rapid increase in surface ozone concentrations in this region. Worryingly, yield reductions of 20 to 35 per cent have been recorded for various crop species when comparing yield in clean air with that in current ambient ozone concentrations in South-East Asia.

10. Asian crop yield and economic loss assessments made using North American or similar European-based dose-response relationships may underestimate the damage caused by ozone. As such, there is an urgent need for coordinated experimental field campaigns to assess the effects of ozone across South-East Asia (and the rest of Asia) to allow the development of dose-response relationships for Asian cultivars and growing conditions leading to improved quantification of current and future impacts of ozone on food production.

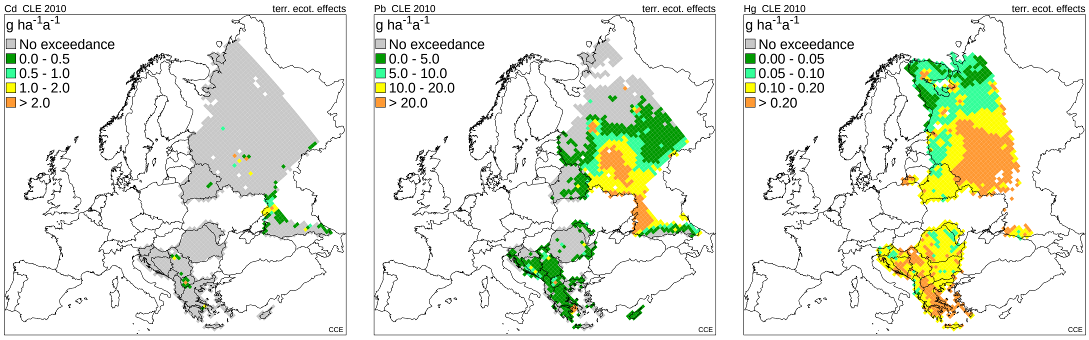
IV. Heavy metals

11. Generally, deposition of heavy metals has declined in recent decades in countries of Eastern and South-Eastern Europe, the Caucasus and Central Asia, in agreement with the general decline computed for the rest of Europe, with the highest decline being reported for lead. However, apart from the western part of the Eastern Europe, the Caucasus and Central Asia region, the decline has generally been lower for those countries compared with the rest of Europe. In 2011, the highest levels of metal deposition were computed in countries of South-Eastern Europe and in the south-western part and some eastern and south-eastern parts of the Eastern Europe, the Caucasus and Central Asia region. This might explain the relatively high concentrations of many heavy metals in mosses in countries in South-Eastern Europe compared with the rest of Europe in recent years. High critical load exceedances have been reported for the former Yugoslav Republic of Macedonia for cadmium and lead and for Bosnia and Herzegovina and the Russian Federation for lead (figure 4). Widespread exceedance of the critical load for mercury has been observed in this region, similar to the rest of Europe. In India, the deposition of many heavy metals onto fruit and vegetables has been found to exceed World Health Organization and Indian national limits for safe consumption.

[6] Ibid.

Figure 4

Average accumulated exceedance of critical loads for cadmium (left), lead (middle) and mercury (right) for terrestrial ecological effects in 2010 in Eastern and South-Eastern Europe



Source: CCE.

V. Persistent organic pollutants

12. Model assessment by EMEP/MSC-E indicates a reduction of POP pollution in most of the countries in Eastern and South-Eastern Europe, the Caucasus and Central Asia between 1990 and 2011, particularly for hexachlorobenzene, although generally lower than for the rest of Europe, with the highest reductions observed in the western part of the region. In 2011, the highest deposition for benzo[a]pyrene and polychlorinated dibenzodioxins were computed in the south-western part of the region, whereas hexachlorobenzene levels were high for large parts of the Russian Federation.

VI. Aerosols, including black carbon as a component, in South Asia

13. South Asia is a region with high aerosol load compared with other regions, due to its rapid growth and the arid climate. In particular the Indo-Gangetic Plain, South Asia’s most important agricultural region, persistently has a very high aerosol load, reducing visibility as well as solar radiation reaching the surface. Reduced photosynthesis might occur as a result of reduced solar radiation and larger aerosols blocking leaf pores, although the increase in diffuse radiation might have the opposite effect on photosynthesis.

VII. Conclusions and recommendations

14. There is a lack of monitoring data regarding the deposition to and impacts of air pollutants on vegetation in countries of Eastern and South-Eastern Europe, the Caucasus and Central and South-East Asia. It would be desirable to further enlarge coordinated networks to measure air concentrations and depositions of air pollutants, i.e., to extend the EMEP monitoring network in the Eastern and South-Eastern Europe, the Caucasus and Central Asia region and to establish a similar network in South-East Asia, for example by extending the Acid Deposition Monitoring Network in East Asia (EANET) by including other regions and more pollutants. International Cooperative Programmes of the Convention might consider further stimulating the development of coordinated networks in these regions with the aim to establish widespread monitoring networks assessing the impacts of air pollutants on ecosystems. More measurement data are urgently needed to validate model outputs regarding the concentrations, depositions and associated risks for

impacts of air pollutants on vegetation. The successful implementation of air pollution abatement policies in many other parts of Europe has highlighted the slower progress made in the abatement of some air pollutants in the countries of Eastern and South-Eastern Europe, the Caucasus, Central and South-East Asia. Improvement of air quality in these regions will also benefit the rest of Europe due to a reduction in the long-range transport of air pollutants, particularly those of hemispheric nature such as ozone and mercury. Many air pollution issues remain in the areas studied that require urgent attention, especially in areas of fast economic and population growth, in particular how to ensure future sustainable development without significant impacts on the functionality of ecosystems, the services they provide and food production.