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

Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

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Item 4 of the provisional agenda
Progress in activities in 2018 and further development of effects-oriented activities

Effects of air pollution on natural vegetation and crops

Report by the Programme Coordinating Centre of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops

Summary

The present report is submitted for consideration by the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and the Working Group on Effects at their fourth joint session, as requested by the Executive Body for the Convention on Long-range Transboundary Air Pollution in the 2018-2019 workplan for the implementation of the Convention (ECE/EB.AIR/140/Add.1 items 1.1.1.12-14) and in accordance with the activities set out in the informal document submitted to the Executive Body for the Convention at its thirty-seventh session entitled “Draft revised mandates for scientific task forces and centres under the Convention”.

The report presents the outcome of ozone-related activities; the 2015-2016 survey on the concentration of heavy metals, nitrogen and persistent organic pollutants in mosses; and the thirty-first meeting of the Programme’s Task Force, held in Dessau-Roßlau, Germany from 5 to 8 March 2018.

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I. Introduction

1. The present report of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) is submitted for consideration by the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects, at the request of the Executive Body for the Convention on Long-range Transboundary Air Pollution in the 2018-2019 workplan for the implementation of the Convention ((ECE/EB.AIR/140/Add.1 items 1.1.1.12-14) and in accordance with the activities set out in the informal document submitted to the Executive Body for the Convention at its thirty-seventh session entitled “Draft revised mandates for scientific task forces and centres under the Convention”. It presents the outcome of ozone-related activities and of the 2015-2016 survey on the concentrations of heavy metals, nitrogen and persistent organic pollutants in mosses. The lead country for ICP Vegetation is the United Kingdom of Great Britain and Northern Ireland and the Programme Coordination Centre is located at the Centre for Ecology & Hydrology in Bangor, United Kingdom. ICP Vegetation has over 250 participants in some 50 countries, including outreach to countries that are not Parties to the Convention.

II. Workplan items

A. Improving and validating the soil moisture index in the EMEP model (item 1.1.1.12)

2. The EMEP Meteorological Synthesizing Centre-West (MSC-W) has provided modelled soil moisture index data to ICP Vegetation for comparison with site-specific soil moisture data measured in Italy, Spain and Switzerland. Analyses are ongoing with a view to improving the application of large-scale flux-based ozone risk assessment using the EMEP model, especially for dry (soil moisture limited) regions such as the Mediterranean and Central and Eastern Europe and under future climate change scenarios.

B. Report on available evidence of ozone impacts on crops in developing regions (item 1.1.1.13)

3. A literature review shows that field-based evidence of ozone impacts on crops in countries receiving official development assistance (ODA) are hardly being investigated or reported.[1] The areas for which the least data is available are Africa, most of Central and South America, and South-Eastern and Eastern Europe, The Caucasus and Central Asia. In the last 15 years, considerable evidence of ozone impacts on crops has emerged from a limited number of locations in China, India and, to some extent, Pakistan. The reduction of crop yield losses due to ozone in these countries is often in the range of 5-20 per cent, bearing in mind that crop species and varieties vary in their sensitivity to ozone. Similar losses were reported for a modelling study on the staple crops wheat, rice, soybean and

[1] Harry Harmens and others, “Evidence of ozone effects on crops in ODA countries: field data and modelling”. ICP Vegetation report for the United Kingdom Department for Environment, Food and Rural Affairs (Defra) (contract No. AQ0846) (Bangor, 2018).

maize for the years 2010-2012[2]. The mean modelled percentage yield losses for four major regions (South and Eastern Asia; Africa; Central and South America; and South-Eastern and Eastern Europe, The Caucasus and Central Asia) were 3.3-5.3, 4.5-7.6, 5.3-10.0 and 7.4-15.3 per cent for rice, maize, wheat and soybean, respectively.

C. Final report of the 2015-2016 survey on heavy metals, nitrogen and persistent organic pollutant concentrations in mosses (item 1.1.1.14)

4. Data on the concentrations of heavy metals in mosses from some 5,000 sites in 34 countries, including eight in South-Eastern Europe and nine in Eastern Europe, the Caucasus and Central Asia (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Republic of Moldova, Russian Federation, Tajikistan and Ukraine), were submitted in 2015 and 2016. Ten countries reported on nitrogen concentrations in mosses and six submitted data on selected persistent organic pollutants (POPs) from selected sites. The data confirm the previously observed spatial patterns for many metals and for nitrogen, i.e. an east-west gradient with concentrations higher in (South-)Eastern than in Western Europe and the lowest concentrations found in Northern Europe. Although the metal and nitrogen concentrations in mosses have continued to decline in some countries, many have reported no change, or even a slight rise, in concentrations since 2010-2011.

III. Progress with core activities

A. Ozone-critical levels for vegetation

5. At the thirtieth meeting of the ICP Vegetation Task Force (Poznan, Poland, 14-17 February 2017), the Task Force adopted 21 ozone-flux-based critical levels for vegetation (ECE/EB/AIR/2017/3 and ECE/EB/AIR/2017/14). Further details are available in the revised chapter 3 (Mapping critical levels for vegetation) of the *Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends* (Modelling and Mapping Manual) with supplementary information available in its Scientific Background Document A.[3] Scientific Background Document B[3] contains flux model parameterizations for additional plant species and information with a view to identifying areas for ozone research and the application of methodologies for the further establishment of flux-based ozone-critical levels for vegetation in the future. These new areas include the soil moisture index in the EMEP model (see paragraph 2 above); the ozone-flux-effect relationships for tree annual increments; plant development in a changing climate; epidemiological analysis of ozone impacts on vegetation; and new statistical approaches to the analysis of flux-effect relationships.

6. A recent study[4] on wheat shows that ozone-flux-effect relationships are not affected by the profile of ozone exposure, i.e. peak episodes or rising background concentrations of ozone. Hence, flux-effect relationships based on enhanced peak ozone concentrations are

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[2] Gina Mills and others, "Closing the global ozone yield gap: Quantification and co-benefits for multi-stress tolerance", *Global Change Biology*, (August 2018), available at https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14381.

[3] http://icpvegetation.ceh.ac.uk/manuals/mapping_manual.html.

[4] Harry Harmens and others, "Wheat yield responses to stomatal uptake of ozone: Peak vs rising background ozone conditions", *Atmospheric Environment*, vol. 173 (January 2018), pp. 1-5.

also valid for application in the currently-changing European ozone profile with higher background and lower peak concentrations.

B. Global flux-based risk of ozone impacts on crops (2010-2012): comparison with effects of other stresses

7. A global flux-based modelling assessment shows that ozone (2010-2012 mean) reduces global yield annually by 12.4, 7.1, 4.4 and 6.1 per cent for soybean, wheat, rice and maize, respectively, for a total of 227 teragrams (Tg) in lost yield. The highest ozone-induced production losses are in North and South America for soybean, in China and India for wheat, in parts of Bangladesh, China, India and Indonesia for rice and in China and the United States of America for maize. Crucially, the same areas are often also at risk of high losses from pests and diseases, heat stress and, to a lesser extent, aridity and nutrient stress. Tolerance of multiple stresses, including ozone, should be included in crop breeding programmes that address the yield gap for crops. It has also been shown that ozone impacts on wheat yield are particularly great in humid, rain-fed and irrigated areas of major wheat-producing countries.[5] Total production losses for wheat in developing countries receiving ODA are 50 per cent higher than in developed countries, reducing the potential for achievement of Sustainable Development Goal 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture). Ozone could also reduce the potential yield benefits of increasing irrigation usage in response to climate change because added irrigation increases the uptake and subsequent negative effects of ozone.

IV. Expected outcomes and deliverables over the next period and in the longer term

8. Over the next period and in the longer term, ICP Vegetation is expected to work and report on:

(a) The development of ozone-flux maps adapted for soil moisture limited areas (in collaboration with MSC-W);

(b) New evidence of ozone impacts on crops in developing regions (and impacts on global food production in the longer term);

(c) Knowledge transfer of ozone risk assessment methodologies to developing regions;

(d) Ozone risk maps for regions and scenarios of the EMEP Task Force on Hemispheric Transport of Air Pollution (in collaboration with MSC-W);

(e) Interactive impacts of ozone and nitrogen on vegetation;

(f) New evidence of nitrogen impacts on (semi-)natural vegetation, in collaboration with the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping);

(g) The 2020 survey on heavy metals, nitrogen and POPs concentrations in mosses, including an update of the moss monitoring manual.

[5] Mills et al. (2018). "Ozone pollution will compromise efforts to increase global wheat production". *Global Change Biology* 2018:1-15.

V. Policy-relevant issues, findings and recommendations

9. See ECE/EB.AIR/GE.1/2018/3-ECE/EB/AIR/2018/3 and paragraphs 3, 4, 6, 7 and 13 of the present report.

VI. Issues for the attention and advice of other groups, task forces or subsidiary bodies, notably with regard to synergies and possible joint approaches or activities

10. Issues for the attention and advice of other groups, task forces or subsidiary bodies include:

(a) Collation of further field-based evidence of the impacts of ozone on vegetation and co-location of sites for the collection of mosses in order to determine their heavy metal and nitrogen concentrations, in collaboration with the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests);

(b) Monitoring of ozone-induced foliar injury and nitrogen concentrations in mosses and calculation of site-specific exceedance of critical ozone-flux-based levels for vegetation, in collaboration with the member States of the European Union and the European Commission as indicators for reporting under Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC (the National Emission Ceilings Directive); and, in that connection, provision of technical support to member States;

(c) Further development of the flux-based ozone risk assessment methodology and its application to vegetation, in collaboration with the EMEP Centre for Integrated Assessment Modelling, ICP Forests, MSC-W and the Convention on Long-range Transboundary Air Pollution Task Forces on, respectively, Hemispheric Transport of Air Pollution and Integrated Assessment Modelling. The ozone-flux-based risk assessment methodology should be applied globally to a range of vegetation types (including crops) and to future air pollution abatement and climate change scenarios;

(d) Collation of new evidence of nitrogen impacts on (semi-)natural vegetation with a view to a review of current empirical nitrogen critical loads, in collaboration with ICP Modelling and Mapping;

(e) Assessment of temporal trends and changes in spatial patterns in heavy metal deposition, in collaboration with the EMEP Meteorological Synthesizing Centre-East.

VII. Enhance the involvement of countries in Eastern Europe, the Caucasus and Central Asia

11. In order to further strengthen implementation and ratification of the Protocols to the Convention in Eastern and South-Eastern Europe, the Caucasus and Central Asia, further evidence of air pollution deposition to and impacts on vegetation in the countries of those subregions should be sought through increased participation in the work of ICP Vegetation. This effort is being promoted by:

(a) The Moss Survey Coordination Centre in Dubna, Russian Federation;

(b) Knowledge transfer through meetings or workshops and the publication of reports, the Modelling and Mapping Manual and leaflets in the Russian language;

(c) Encouraging experts from those countries to attend meetings of the ICP Vegetation Task Force.

VIII. Outreach activities outside the United Nations Economic Commission for Europe region

12. ICP Vegetation will pursue and further promote collaboration with African, Asian and South-American countries. An ICP Vegetation-Asia network was established at an ozone training workshop hosted by the Programme Coordination Centre in the autumn of 2017, initially in order to collate new evidence of ozone impacts on crops. In the context of activities on the theme “Seeing is believing”, network members will grow sensitive ozone species (SOS) in order to assess ozone-induced visible leaf damage under ambient conditions. The aim is to show policymakers and other stakeholders that ozone adversely affects not only human health, but also food production. ICP Vegetation also co-organized the International Conference on Ozone and Plant Ecosystems (see para. 17 below).

13. The Tropospheric Ozone Assessment Report (TOAR) on the current state of knowledge of ozone metrics of relevance to vegetation (TOAR-Vegetation)[6] covers the present-day global distribution of ozone at over 3,300 vegetated sites and the long-term trends in vegetation-relevant metrics at nearly 1,200 sites. Although the density of measurement stations varies widely across regions, in general the highest ozone values (mean for 2010-2014) are in the middle latitudes of the northern hemisphere, including the southern United States; the Mediterranean basin; northern India; northern, north-western and eastern China; Japan; and the Republic of Korea. The lowest metric values reported were in Australia, New Zealand, southern South America and some northern parts of Europe, Canada and the United States. During the period 1995-2014, the dominant trend in North America was a significant decrease in ozone whereas there was no change in Europe and a significant increase in East Asia. TOAR-Vegetation provides recommendations designed to facilitate a more complete global assessment of ozone impacts on vegetation in the future, including increased monitoring of ozone; a more coordinated effort to collate field evidence of damaging effects on vegetation; the inclusion of additional pollutant, meteorological and inlet height data in the TOAR dataset; the establishment of new vegetation- and region-specific thresholds for damage; and the innovative integration of observations and modelling, including with regard to ozone flux.

IX. Scientific findings: highlights

14. Highlights of the scientific findings of ICP Vegetation are summarized in the 2018 joint progress report on policy-relevant scientific findings (ECE/EB.AIR/GE.1/2018/3–ECE/EB.AIR/WG.1/2018/3) and in paragraphs 3, 4, 6, 7 and 13 of the present report.

[6] Gina Mills and others, “Tropospheric Ozone Assessment Report: Present-day tropospheric ozone distribution and trends relevant to vegetation”. *Elementa - Science of the Anthropocene*, 28 June 2018. Available at https://www.elementascience.org/article/10.1525/elementa.302/.

X. Meetings

15. The thirty-first meeting of the Programme Task Force was held in Dessau-Roßlau, Germany, from 5 to 8 March 2018. The meeting, by the Umweltbundesamt (UBA) and organized in cooperation with the Justus Liebig University Giessen and the Thünen Institute, was attended by 73 experts from 23 countries, including Armenia, Belarus, Georgia, Kazakhstan and the Russian Federation.

16. The ICP Vegetation Programme Coordination Centre and the International Union of Forest Research Organizations (IUFRO) organized the International Conference on Ozone and Plant Ecosystems (Florence, Italy, 21-25 May 2018). The Conference was attended by 100 experts from 30 countries, including in Africa, Asia and South America. Raising awareness of the global threat of ozone pollution to food production and terrestrial ecosystems was identified as one of the major challenges for the future.

XI. Publications

17. For a list of ICP Vegetation publications and references for the present report, please visit the ICP Vegetation website.[7]

[7] http://icpvegetation.ceh.ac.uk/publications/.