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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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Progress in activities and workplan for 2024–2025 of effects-oriented activities: air pollution effects on materials, the environment and crops: air pollution effects on vegetation

Effects of air pollution on natural vegetation and crops

Report by the Programme Coordination 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 ninth joint session, in accordance with both the 2022–2023 workplan for the implementation of the Convention (ECE/EB.AIR/148/Add.1, workplan items 1.1.1.13, 1.1.1.14, 1.1.1.15, and 1.1.1.16) and the Revised mandate for the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (Executive Body decision 2019/17).

The report presents the outcome of ozone-related activities; the monitoring survey on the concentration of heavy metals, nitrogen and persistent organic pollutants in mosses; and the thirty-fourth meeting of the Programme's Task Force (online, 13–15 February 2023).

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 2022–2023 workplan for the implementation of the Convention (ECE/EB.AIR/148/Add.1, workplan items 1.1.1.13, 1.1.1.14, 1.1.1.15, and 1.1.1.16) and in accordance with the Revised mandate for the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (Executive Body decision 2019/17).[1] It presents the outcome of ozone-related activities and of the 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 United Kingdom Centre for Ecology & Hydrology, Bangor, the United Kingdom of Great Britain and Northern Ireland. ICP Vegetation has over 300 participants in some 63 countries, including outreach to countries that are not Parties to the Convention.

II. Workplan items

A. Ozone flux-based risk assessment for vegetation for air pollution scenarios (item 1.1.1.14)

2. The ICP Vegetation Coordination Centre produced maps, tables and a short report summarizing the impacts of ozone on crops and deciduous trees for the review of the Gothenburg Protocol, as amended in 2012 (Executive Body decision 2019/4) in collaboration with the Meteorological Synthesizing Centre-West and using the Baseline, Maximum Feasible Reduction and Low scenarios for the years 2015, 2030 and 2050 from the Centre for Integrated Assessment Modelling. Production losses of wheat take into account the combination of percentage yield loss and wheat production. For the countries with the highest wheat production, analysis showed that although there are improvements in production losses with the Maximum Feasible Reduction and Low scenarios, particularly by 2050, significant production losses of wheat due to ozone will still occur. For the most stringent of the scenarios tested it is predicted that in 2050 for the top 10 wheat producing countries there would still be a total loss of 13 million tonnes of wheat annually due to ozone pollution.

3. The percentage reduction in biomass growth increment for deciduous trees was shown to be highest in Italy and parts of central-southern Europe (e.g. Bulgaria, Hungary, Slovenia and Romania). In 2015 estimated losses of 20% were widespread across much of central mainland Europe. As for wheat yield, although showing improvements, significant reductions in biomass increment were still predicted to occur by 2050 even using the most stringent scenario.

B. Review of ozone pollution and climate change impacts on vegetation (focus on implications for calculation and application of flux-based Critical Levels and risk assessment (item 1.1.1.15))

4. Accelerated chlorophyll reduction in leaves due to ozone has been found to be a major contributing factor to yield loss. Chlorophyll reduction is also influenced by climate change stresses and as such is already incorporated as an important physiological process into several existing crop models. Work is ongoing to incorporate the ozone influence on this process into these existing models so that the combined influence of ozone and climate change can be applied across a range of global regions.

[1] Available at www.unece.org/env/lrtap/executivebody/eb_decision.html.

5. For India, application of an ozone-flux-based risk-assessment with the DO_3SE model showed that ambient ozone levels cause a mean 14% reduction in wheat yields during 2008-2012. Irrigated wheat was particularly sensitive to ozone-induced yield losses, indicating that ozone pollution could undermine climate-change adaptation efforts through irrigation expansion.

6. In addition to effects via ozone flux, some new information has shown that ozone and climate stress could have combined effects on nutritional quality of crops. Ozone, heat and drought have been shown to affect the nutrition of wheat grains, including micronutrients such as calcium and zinc.

C. State of knowledge report on genetics of crop resilience to ozone and potential for crop breeding (item 1.1.1.16)

7. A literature review by ICP Vegetation on genetics of crop resilience to ozone is in progress. Preliminary findings are that some genes associated with ozone tolerance have been found in rice and soybean, but that there is limited knowledge relating to the genetic background to ozone tolerance in wheat. However, the wild relatives of wheat retain greater genetic diversity than that which is contained within the hexaploid genome, and this genetic diversity could be exploited to enhance resilience to ozone and other stresses in modern cultivars. To date, many older varieties of crops, particularly wheat and soybean, are more tolerant to ozone than the more recently released cultivars, however, a variety in ozone sensitivity of synthetic hexaploid wheat, which is a result of modern artificial re-crossing, has been found.

D. Call for submission of data on heavy metal, nitrogen and persistent organic pollutants concentrations in mosses to be sampled in 2020-2022 (item 1.1.1.13)

8. The coordination of the Moss survey, including data analysis and writing the report on the 2020-2022 survey has been transferred back to the PCC. Delivery of the final report is expected in 2024. The survey will continue to focus on a suite of metals, and covers those that have declined in many countries over recent years as a result of reduced emissions (e.g. lead) in addition to those that remain a cause for concern (e.g. mercury).

9. A new study on airborne microplastic deposition to mosses (MADAME) was launched and participants from >30 countries across Europe have submitted samples for parallel analysis by three laboratories. Laboratory analysis is ongoing and polymers detected to date include polyurethane, which has very wide-ranging applications, from its use in clothing, to its application as a coating and binder, from flexible foams used in construction, to insulation in home furnishings and appliances.

III. Progress with other core activities

A. Ozone critical levels for vegetation

10. At its thirty-sixth meeting (online, 13–15 February 2023), the ICP Vegetation Task Force reviewed the potential chapters of *Scientific Background Document B*, providing supplementary information to chapter 3 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).[2] These chapters contain information on advances in the state of knowledge relevant to ozone impacts on vegetation and for mapping ozone

[2] Till Spranger, Ullrich Lorenz and Heinz-Detlef Nagel, eds. (Berlin, German Federal Environmental Agency, 2004).

impacts on vegetation. Subjects of future new chapters include: ozone removal by vegetation in urban areas; and impacts of ozone on pasture quality.

B. Update of evidence of ozone impacts on crops in developing regions

11. Using institutional funds, the Programme Coordination Centre has engaged with local scientists in developing regions in order to initiate the collection of some observations and data on ozone concentrations and impacts on crops. Ozone diffusion tubes were distributed to sites in Brazil (Eucalyptus plantation and native vegetation), Ecuador (across an elevation gradient), Ghana, Kenya, Malawi (high and low elevation) and Zambia to monitor ambient ozone over a period of three months. These are countries where ozone concentration measurements are scarce. Although the diffusion tubes only reflect the average ozone concentration, rather than the magnitude of peaks and troughs, these can still indicate where ozone might be a cause for concern. At a high elevation site in a cedar plantation on Mt. Mulanje, Malawi the high average concentration of 53 ppb would be anticipated to give large negative effects on vegetation. Similarly in Brazil the 30 – 35 ppb average concentrations in a eucalyptus forest and a mixed forest would be anticipated to give negative effects on growth, photosynthesis and carbon sequestration.

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

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

(a) Ozone flux-based risk maps for vegetation for various air pollution emission scenarios to support the follow-up to the review of the Gothenburg Protocol, in collaboration with the Task Force on Integrated Assessment Modelling, the Centre for Integrated Assessment Modelling and the Meteorological Synthesizing Centre-West;

(b) Ozone flux-based risk maps for vegetation for various methane scenarios, in collaboration with the Task Force on Hemispheric Transport of Air Pollutants, Task Force on Integrated Assessment Modelling, the Centre for Integrated Assessment Modelling and the Meteorological Synthesizing Centre-West;

(c) Further development and application of the ozone-modified photosynthesis-based flux-response models (in collaboration with the Meteorological Synthesizing Centre-West);

(d) Inclusion of ozone damage functions in crop growth models (in collaboration with the Agricultural Model Intercomparison and Improvement Project;

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

(f) Review of ozone pollution impact on carbon sequestration by trees in Europe;

(g) Report on the 2020–2022 survey on heavy metals, nitrogen and persistent organic pollutants concentrations in mosses;

(h) Report on the microplastic content of mosses from the pilot study in 2022/2023;

(i) Review of critical levels of nitrogen oxides for vegetation.

V. Policy-relevant issues, findings and recommendations

13. For information on policy-relevant issues, findings and recommendations, see 2023 Joint progress report on policy-relevant scientific findings, and paragraphs 2, 3, 5 and 9 above.

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

14. 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 the National Emission Ceilings Directive,[3] and, in that connection, provision of technical support to member States;

(c) Further application of the flux-based ozone risk assessment methodology for vegetation, in collaboration with the Centre for Integrated Assessment Modelling, ICP Forests, the Meteorological Synthesizing Centre-West, the Task Force on Hemispheric Transport of Air Pollution and the Task Force on Integrated Assessment Modelling. The flux-based ozone risk assessment methodology should be applied: at a range of scales (from local to global); to a range of vegetation types (including crops); and to current and future air pollution abatement and climate change scenarios, including additional scenarios agreed to support a review of the Gothenburg Protocol;

(d) Further development and application of the ozone-modified photosynthesis-based flux effect relationships in the EMEP model, in collaboration with the Meteorological Synthesizing Centre-West;

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

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

15. 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, Dubna, the Russian Federation (until February 2023);

(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 ICP Vegetation Task Force meetings.

[3] 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, *Official Journal of the European Union*, L 344 (2016), pp. 1–31.

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

16. ICP Vegetation will pursue and further promote collaboration with African, Asian and South American countries. An ICP Vegetation-Asia network was established in 2017 to collate new evidence of ozone impacts on crops.

17. Using institutional funds, the Programme Coordination Centre has conducted the following outreach activities:

(a) Provision of ozone 'diffusion tubes' to monitor ozone concentration (see above);

(b) Production of ozone injury factsheets for crops for plant health doctors as part of the "Plantwise" programme in Africa;[4] https://plantwiseplusknowledgebank.org/doi/10.1079/pwkb.20237800003;

(c) Alongside scientists in India, parameterise the DO_3SE model for local cultivars of bean to allow a local risk assessment of ozone-induced yield losses;

(d) Development of a nitrogen module within the DO_3SE model to allow an assessment of ozone impacts on crop quality (in terms of protein content of grains) for wheat, initially with a focus on India;

(e) Detailed assessment of ozone impacts on bean yield in Uganda, highlighting the importance of local impacts for subsistence agriculture;

18. ICP Vegetation will continue to collaborate with the Tropospheric Ozone Assessment Report[5] initiative and to support the implementation of the DO_3SE ozone flux model into the web service architecture;

19. Several countries from outside the United Nations Economic Commission for Europe (ECE) region are participating in the Moss Survey 2020–2022.

IX. Scientific findings: highlights

20. Highlights of the scientific findings of ICP Vegetation are summarized in the 2023 joint progress report on policy-relevant scientific findings and in paragraphs 2, 3, 5 and 9 above.

X. Meetings

21. The thirty-sixth meeting of the Programme Task Force was held online and hosted by the UNECE. The meeting was attended by 110 participants from 36 countries, including some experts from countries from outside the ECE region. Minutes of the meeting are available from the ICP Vegetation website.[6]

XI. Publications

22. For a list of ICP Vegetation publications and references for the present report, please visit the ICP Vegetation website.

[4] See www.plantwise.org.
[5] See www.igacproject.org/activities/TOAR.
[6] See https://icpvegetation.ceh.ac.uk.