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Working Group on Effects

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Progress in activities in 2024 and further development 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 tenth joint session, in accordance with both the 2024–2025 workplan for the implementation of the Convention (ECE/EB.AIR/154/Add.1) 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-seventh meeting of the Programme’s Task Force (Kaunas, Lithuania, 19–22 February 2024).

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 2024–2025 workplan for the implementation of the Convention (ECE/EB.AIR/154/Add.1) 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. Assessment of airborne deposition to mosses relating to a) the call for data for the 2025 survey on heavy metals, N, POPs and microplastics, b) the results of the 2020/21 moss survey on heavy metals, N and POPs, and c) the survey of microplastic content to mosses (item 1.1.1.11)

2. A protocol for the 2025 survey has been drafted and agreed, based on decisions made at previous Task Force Meetings of the ICP Vegetation. The protocol is similar to previous versions, to facilitate comparison of data from previous surveys and identification of trends in metal concentration within the mosses over time. The main amendments to the protocol are to reflect updated guidance when sampling beneath tree canopies, and to provide sample collection and analysis guidance for microplastics.

3. The ICP Vegetation Coordination Centre have produced maps based on the results of the 2020/21 moss survey for the metals Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sb, V, and Zn, and also for nitrogen. For this survey, a colour-blind friendly colour scheme has also been introduced for presenting results. These show that similar to previous years, for many metals there is a trend for increased content within the moss tissue for samples from the south-eastern part of the region compared to the north and north-west. For copper, cadmium and zinc some individual countries have reported either no change since the previous survey, or even a possible slight increase in metal content within the moss tissue (although concentrations remain low compared to historic surveys). It is possible that these may be associated with vehicle use including lubricants and brake and tyre wear (copper and zinc), in addition to domestic wood burning (cadmium), although this is currently unconfirmed and will be investigated further using the complete dataset. Nitrogen content of moss tissue remains high across central Europe.

4. Although laboratory analysis is ongoing for the new study on microplastic deposition to mosses (MADAME), data to date has shown that airborne microplastics are found throughout the UNECE region, even in rural areas such as Scandinavia and western Ireland. Moss is difficult to chemically digest in large quantities, and some new techniques have been developed as part of this work. The study has confirmed that mosses can be used as a biomonitor for airborne deposition of microplastics. The MADAME project has found a wide range of microplastics in moss samples, including from textiles and plastic litter. The types of polymer include polyurethane, cellulose acetate and polyethylene. No difference in microplastic concentration was found between the two most commonly sampled moss species in the UK. The two species were *Hylocomium. splendens* and *Pleurozium schreberi,* which have a similar physical structure and implies that similar deposition mechanism and dynamics occur across different moss species. Although microplastics have been found in moss samples from across the region, questions remain about sources, retention time in moss, whether microplastics are internal to the moss tissue or remain external, and possible impacts on vegetation and the wider ecosystem.

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

B. State of knowledge report: Impacts of ozone on carbon sequestration in Europe (item 1.1.1.12)

5. A state of knowledge report by ICP Vegetation on impacts of ozone on carbon sequestration in Europe is in progress. Using ozone flux data and existing flux-response relationships ICP Vegetation have shown that there are widespread reductions in growth of deciduous trees across much of the EMEP domain due to ozone. Modelling based on the year 2015 showed that percentage losses of annual growth were highest in Italy and in the South-East of the region, and with reduction in annual growth increment of >15% across much of central Europe. Countries with notably high losses include Italy (25.5%), Slovenia (24.2%), Croatia (23.5%), Bulgaria (23.3%) and Albania (22.9%). These model results are of a similar magnitude to those found in previously published studies from Switzerland and Sweden that used an epidemiological approach to link measured changes in tree growth and relating these changes to meteorological and pollution parameters including ozone. As forest ecosystems have the greatest carbon sink capacity of any vegetation type, and hold the largest amount of biomass carbon, ozone impacts on tree biomass have the potential to have major repercussions for the carbon cycle and carbon sequestration. Previous work by ICP Vegetation participants calculated that ozone flux was responsible for a reduction of 1249 to 1929 Mt C in the EU+NO+CH region in 2000.

C. Review of critical levels for NOx (item 1.1.1.13)

6. Analysis of published literature has shown that although NO and NO_2 have different effects on vegetation, and at different concentrations, there is insufficient evidence to justify separate critical levels for NO and NO_2. A review of the literature has shown that in many countries NO_2 concentrations have been declining over recent decades, however, concentrations can remain high enough to impact vegetation, particularly near to roadsides. There may also be impacts on other ecosystem components at these concentrations. Additional data from experimental studies published since the critical levels for NOx were established and that is of relevance to reviewing critical levels of NOx have been extracted and collated. There is also supporting information from gradient studies that progress away from roadsides. Some additional data analysis is required since the atmospheric composition of other pollutants has changed drastically since critical levels of NOx were previously set and agreed, and some of these other pollutants influence the response of vegetation to NOx.

7. Using institutional funds it was found that the combination of ozone and nitrogen dioxide pollution have the potential to disrupt grassland habitats via impacts on pollinators, which are vital components of a healthy ecosystem. Impacts are from a combination of reduced flower numbers due to ozone, altered floral VOC emission by plants, and degradation of the floral VOC signal by ozone and NOx. The study has highlighted potential areas at risk of ozone and NO_2 pollution in the USA and UK, and these included important grassland habitats in both countries.

III. Progress with other core activities

A. Ozone critical levels for vegetation

8. At its thirty-seventh meeting (Kaunas, Lithuania, 19–22 February 2024), 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 impacts on vegetation. Inclusion of a new chapter on “Handling of soil moisture effect

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

on ozone flux for large-scale modelling using the soil moisture index" was agreed. The updated chapter includes new species-specific fSMI parametrizations for flux-based ozone risk assessment in water-limited areas. This update is the result of the activity on validation of soil moisture index used in EMEP model coordinated by CIEMAT (Spain), with contributions from CEAM (Spain), Unicatt (Brescia, Italy) and EMEP Meteorological Synthesizing Centre-West.

9. Progress has continued with development of a nitrogen module for the DO_3SE model. Ozone influences the nitrogen dynamics of wheat, in addition to the impacts on yield. The new module will allow investigation of the influence of ozone on nutrition (protein content) of wheat, which will be particularly important for developing countries where ozone concentrations are high.

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

10. The ICP Vegetation has continued to collate new evidence of ozone impacts on crops relevant to developing regions, with the aim to compile information on the relative sensitivity to ozone of tropical crops. The most recent data shows that many of the widely grown tropical crops are sensitive to ozone (based on ozone concentration), including bean, chickpea, cowpea, leafy vegetables, maize and sweet potato, whereas barley is moderately sensitive and millets appear tolerant.

11. The ICP Vegetation worked with researchers in India to assess eight Indian bean (*Phaseolus vulgaris* L.) genotypes for ozone biomonitoring potential, along with the pre-identified ozone-sensitive (S156) and ozone-resistant (R123) bioindicator *Phaseolus* genotypes used within the ICP Vegetation. One set of replicates was treated with the ozone protectant EDU, while the other set was left under ambient environmental conditions without any treatment. This provided evidence of ozone impacts on crops in India. The genotypes exposed to ambient O_3 exhibited 0%-40% foliar ozone injury, though the timing of appearance of foliar O_3 injury symptoms was variable among the genotypes, whereas plants treated with EDU exhibited lower foliar injury.

12. Using institutional funding ICP Vegetation in collaboration with scientists in the UK, Italy and Brazil developed a flux-effect relationship for sugarcane and applied this to the main sugarcane production areas of Brazil. This demonstrated that between 5.6 and 18.3% of total sugarcane crop productivity is lost across the region due to ozone exposure.

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

13. 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 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. This will include investigating ozone impacts on grassland across the EMEP domain, which can be linked to impacts on biodiversity. ICP Vegetation plans to use the newly produced by the Coordination Centre for Effects (CCE) harmonised land cover map for data on grassland distribution across Europe;

(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) Report on the 2025–2026 survey on heavy metals, nitrogen and persistent organic pollutants concentrations in mosses.

V. Policy-relevant issues, findings and recommendations

14. For information on policy-relevant issues, findings and recommendations, see 2023 Joint progress report on policy-relevant scientific findings, and paragraphs 3, 4, 5, 6 and 7 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

15. 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, trees and semi-natural vegetation); 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

16. 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

[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.

subregions should be sought through increased participation in the work of ICP Vegetation. This effort is being promoted by:

(a) Knowledge transfer through meetings or workshops;

(b) 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.

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

17. 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.

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

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

(b) Production of ozone injury factsheets for crops for plant health doctors as part of the CABI (Centre for Agriculture and Bioscience International) "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 (see above);

(e) Detailed assessment of ozone impacts on bean yield in Uganda, highlighting the importance of local impacts for subsistence agriculture, now published as an open-access scientific paper in addition to direct knowledge exchange with scientists from Uganda.

19. ICP Vegetation provided assistance with a research study investigating the effects of ozone pollution on leguminous plants in Rajasthan, India, which included calculating the yield loss of legume crops due to ozone (2018–onwards) in different districts across the region.

20. The ICP Vegetation has advised on inclusion of ozone damage functions in crop growth models within the Agricultural Model Intercomparison and Improvement Project. These models are applicable at a global scale and thus will provide important information relevant outside of the UNECE region.

21. 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.

22. Several countries from outside the United Nations Economic Commission for Europe (ECE) region, including Mongolia and Vietnam, have participated in the Moss Survey 2020–2022, and some, including India, have indicated that they intend to participate in the 2025-2026 survey.

[4] See www.plantwise.org.

[5] See www.igacproject.org/activities/TOAR.

IX. Scientific findings: highlights

23. Highlights of the scientific findings of ICP Vegetation are summarized in the 2024 joint progress report on policy-relevant scientific findings and in paragraphs 2, 3, 5 and 9 above.

X. Meetings

24. The thirty-seventh meeting of the Programme Task Force was held in-person and hosted by the Lithuanian Research Centre for Agriculture and Forestry, Lithuania. The meeting was attended by 62 participants, including some experts from countries from outside the ECE region. Minutes of the meeting are available from the ICP Vegetation website.[6]

XI. Publications

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

[6] See https://icpvegetation.ceh.ac.uk.