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Working Group on Effects

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Progress in activities in 2021 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 seventh joint session, in accordance with both the 2020–2021 workplan for the implementation of the Convention (ECE/EB.AIR/144/Add.2, workplan items 1.1.1.9, 1.1.1.21, and 1.4.1–1.4.3) 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, 22–24 February 2021).

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 2020–2021 workplan for the implementation of the Convention (ECE/EB.AIR/144/Add.2, workplan items 1.1.1.9, 1.1.1.21 and 1.4.1–1.4.3) 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 and Hydrology, Bangor, the United Kingdom of Great Britain and Northern Ireland. 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. Review of interactive impacts of ozone and nitrogen on vegetation (item 1.1.1.9)

2. The previous review in 2020 had a focus on crops and has been published as a chapter in *Scientific Background Document B*, available from the ICP Vegetation website.[2] The review concluded that there was no evidence of a requirement to adjust critical levels for ozone effects on crops with respect to nitrogen availability. A similar review for semi-natural vegetation has been performed, which also concluded that there was no evidence of a requirement to adjust critical levels for ozone effects with respect to nitrogen availability. Although there were some notable interactive effects between ozone and nitrogen on semi-natural vegetation for some individual species, the direction and magnitude of effect was not consistent. For some semi-natural vegetation communities, it has been found that combined additions of ozone and nitrogen affected vegetation species composition. Changes in the species community composition can also affect the sensitivity/resilience of a community to ozone. As for crops, ozone decreased the nitrogen use efficiency of some (semi-)natural species and vegetation communities.

B. Ozone flux-based risk assessment for vegetation at various air pollution scenarios (for a potential review of the Gothenburg Protocol) (item 1.4.1)

3. In collaboration with the Meteorological Synthesizing Centre-West, the necessary preparation work has been completed in anticipation of the various air pollution scenarios to be used for a review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol), as amended in 2012 (Executive Body decision 2019/4). The ICP Vegetation has compiled information from various sources in order to assess the change in impacts on crops and ecosystems due to changes in ozone concentrations and fluxes since 1990. The change in ozone profile in terms of the 'background' and 'peaks' of concentrations since 1990 means that, although some metrics, for example, accumulated ozone exposure over a threshold of 40 parts per billion (AOT40), imply a reduction in impacts of ozone on crops and ecosystems, the current preferred metric of ozone fluxes shows a much smaller change in vegetation impacts over the same time period (for example, for wheat yield), and

[1] Available at www.unece.org/env/lrtap/executivebody/eb_decision.html.
[2] See https://icpvegetation.ceh.ac.uk/sites/default/files/Scientific%20Background%20document%20B%20June%202020.pdf.

many areas show no change in growth and yield impacts. Interactions between ozone pollution and climate change, and ozone pollution and nitrogen deposition will be important considerations in the near future when assessing the impacts on crops and ecosystems.

C. Ozone flux-based risk assessments adapted for vegetation in soil moisture limited areas (item 1.4.2)

4. The Meteorological Synthesizing Centre-West has provided modelled soil moisture index data to ICP Vegetation for comparison with site-specific soil moisture data measured in Italy, Spain, Sweden and Switzerland. Preliminary analysis at a site in Spain indicates that the EMEP-modelled soil moisture index mimics well seasonal and inter-annual variation, but slightly overestimates soil moisture on average. The EMEP-modelled soil model index estimates soil moisture less accurately in spring and summer at the site in Spain. Delivery of the final maps and report is now expected at the end of 2021.

D. Test the development and application of photosynthesis-based flux-response models (item 1.4.3)

5. Photosynthesis-based flux-response models are used in some terrestrial biosphere models and could be used to estimate the effect of ozone on carbon assimilation and, ultimately, on crop yield and forest biomass. An ozone-modified coupled stomatal conductance-photosynthesis model has been developed and tested for wheat. This has shown a similar prediction of relative yield with increasing ozone compared to the existing multiplicative stomatal conductance model. Additional data sets will be included and will allow the impact of ozone on potential shortening of the growing season via increased senescence to be evaluated. This is in collaboration with the Meteorological Synthesizing Centre-West, and delivery of the final report is expected in 2021.

E. Call for submission of data on heavy metal, nitrogen and persistent organic pollutants concentrations in mosses to be sampled in 2020/2021/2022 (item 1.1.1.21)

6. In preparation for the moss monitoring survey across Europe and beyond, the "Heavy Metals, Nitrogen and POPs in European Mosses: 2020 Survey: Monitoring Manual"[3] was completed and is available from the ICP Vegetation website. Some countries will also conduct a pilot study on the use of mosses as biomonitors of microplastics; hence, guidance on monitoring microplastics in mosses was included. Some sampling will be moved to 2021/2022 due to travel and field sampling restrictions in place due to the coronavirus disease (COVID-19) pandemic. Moss samples were collected from >1500 sites in 2020.

III. Progress with other core activities

A. Ozone critical levels for vegetation

7. At its thirty-fourth meeting (online, 22–24 February 2021), 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).[4] These chapters contain information on advances in the state of knowledge relevant to ozone impacts on vegetation and for mapping ozone

[3] See https://icpvegetation.ceh.ac.uk/sites/default/files/ICP%20Vegetation%20moss%20monitoring%20manual%202020.pdf.

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

impacts on vegetation. Subjects of future new chapters include: improved phenology for ozone flux modelling in trees; ozone removal by vegetation in urban areas; and impacts of ozone on pasture quality.

8. Parameterizations for the Deposition of Ozone for Stomatal Exchange (DO_3SE) model were developed for selected tropical crops, including bean, sweet potato and finger millet. This will allow risk assessment of additional crops in tropical regions, and is particularly relevant for risk assessments in regions where crops of existing models (for example, wheat) do not grow.

9. The effect of ozone on the carbon sequestration of living biomass of forest trees in Europe was calculated. Ambient stomatal ozone fluxes in 2000 reduced the increase in carbon (C) storage in the living biomass C stocks of ozone-sensitive trees on average by 12.6–17.7 per cent across Europe when applying the EMEP and Rossby Centre Regional Climate (RCA3) model input data, respectively. The highest absolute reductions generally occurred in Finland, France, Germany, Poland and Sweden. The inclusion of the potential for soil water to limit ozone uptake reduced the ozone fluxes and hence C sequestration losses, especially in the Mediterranean countries. The species-specific parameterization led to generally slightly higher fluxes, suggesting that a parameterization only accounting for deciduous and coniferous trees might underestimate the risk ozone poses to C sequestration.

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

10. 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 Ethiopia, India, Malaysia, Uganda, the United Republic of Tanzania and Zambia to monitor ambient ozone over a period of three months. 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 the campus of Varanasi University, India, mean ozone concentrations were recorded as >30 parts per billion (ppb), and likely higher in the surrounding rural areas, as there could be titration of ozone by nitrogen oxides in urban areas. In Uganda, during December–January, mean ozone concentrations were close to 30 ppb in Buginyanya (in the east) and Rwebitaba (in the west), but in Namulonge (in the centre, near to Lake Victoria) mean ozone was approximately 15 ppb. During January–mid-March, the mean ozone concentrations in Uganda were higher, at 36–37 ppb in Buginyanya and Rwebitaba, and >20 ppb in Namulonge. Such concentrations in India are known to give significant reductions in yield of sensitive crops (although the diurnal profile and magnitude of any “peaks” in the ozone concentration might be different in the different locations, and this may influence the crop response).

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

11. 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;

(b) Interactive impacts of ozone and nitrogen on (semi-)natural vegetation;

(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) New evidence of nitrogen impacts on (semi-)natural vegetation to support the review of empirical critical loads for nitrogen, 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) Review of ozone pollution and climate change impacts on vegetation;

(h) The 2020–2022 survey on heavy metals, nitrogen and persistent organic pollutants concentrations in mosses;

(i) Assessing the suitability of mosses as biomonitors of air pollution in the Eastern Europe, the Caucasus and Central Asia region based on the results of the 2015/16 survey.

V. Policy-relevant issues, findings and recommendations

12. For information on policy-relevant issues, findings and recommendations, see 2020 Joint progress report on policy-relevant scientific findings (ECE/EB.AIR/GE.1/2020/3–ECE/EB/AIR/WG.1/2020/3) and paragraphs 2, 3 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

13. 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,[5] 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 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) Collation of new evidence of nitrogen impacts on (semi-)natural vegetation with the aim of reviewing current empirical nitrogen critical loads, in collaboration with ICP Modelling and Mapping;

[5] 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.

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

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

14. 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;

(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.

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

15. 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.

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

(a) Production of a “YouTube” video to give an overview of the impacts of ozone on vegetation and highlight the consequences for crop production;

(b) Organization and delivery of a training seminar on ozone impacts on crops for Tanzanian crop scientists (online, 10 March 2021);

(c) Production of ozone injury factsheets for crops for plant health doctors as part of the “Plantwise” programme in Africa;[6]

(d) Collation of photos of ozone-specific leaf injury for sweet potato, maize, millet and bean, and the production of factsheets tailored to be applicable to tropical countries using examples from these regions where possible.

17. ICP Vegetation will continue to collaborate with the Tropospheric Ozone Assessment Report[7] initiative and to support the implementation of the DO_3SE ozone flux model into the web service architecture.

18. 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

19. Highlights of the scientific findings of ICP Vegetation are summarized in the 2020 joint progress report on policy-relevant scientific findings and in paragraphs 2, 3 and 9 above.

[6] See www.plantwise.org.
[7] See www.igacproject.org/activities/TOAR.

X. Meetings

20. The thirty-fourth meeting of the Programme Task Force was held online and hosted by the United Kingdom Centre for Ecology & Hydrology. The meeting was attended by 125 participants from 35 countries, including some experts from countries from outside the ECE region. Minutes of the meeting are available from the ICP Vegetation website.[8]

XI. Publications

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

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