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Recent results and updating of scientific and technical knowledge

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

I. Introduction

1. Recent results on the effects of ozone on vegetation, and progress with the European moss survey on heavy metals and nitrogen are presented here in accordance with item 3.5 of the 2010 workplan for the implementation of the Convention (ECE/EB.AIR/99/Add.2) adopted by the Executive Body at its twenty-seventh session in December 2009.

II. Workplan items common to all programmes

A. Targets and ex post application

2. The targets for impacts of ozone on vegetation were set to avoid most (by 2020) and all (by 2050) detectable ozone damage to receptors, as well as reduction in ecosystem services, such as carbon sequestration. Indicators are a reduction in (2020) or no exceedance (2050) of flux-based ozone critical levels for vegetation. It was recommended to apply the principal of gap closure to reduce exceedance in 2020. The aim is to secure food production and quality, protect against loss of carbon storage and loss of ecosystem services provided by trees (e.g., flood prevention, protection from soil erosion and avalanches) and protect against loss of fodder quality and vitality of (semi-)natural vegetation. Application in ex post integrated assessment will be conducted once baseline, harmonized data on concentrations and depositions become available.

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B. Robustness

3. Soil moisture, which has the potential to strongly limit ozone uptake by vegetation, varies on a local scale which is hard to model. In experiments used to derive flux-based ozone critical levels for vegetation, soil moisture was typically kept at a level that did not induce any water stress. Although the flux approach represents a way to quantify several of the important factors that modify ozone uptake that may differ between exposure systems and the field, the application of flux-effect relationships still depends on extrapolation from one set of conditions to another. For some Mediterranean areas the flux-based methodology may underestimate effects and for crops a modified vapour pressure deficit function may be required. A recent meta-analysis of results in peer-reviewed studies of ozone effects on wheat indicated that ozone concentrations between 31 and 59 parts per billion (ppb) (average 43 ppb) were associated with a significant decrease in the grain yield (18 per cent) and biomass (16 per cent) relative to charcoal-filtered air treatments. For forest trees, an additional source of uncertainty lies in the application of critical levels derived from effects on trees of up to 10 years of age growing in an exposure facility, to mature trees growing within a forest stand. It is encouraging, however, that an epidemiological study has shown that the flux-based critical level for birch and beech would have protected mature beech trees in Switzerland. In addition, a recent meta-analysis of published data on tree responses indicated that an ambient ozone concentration of ca. 40 ppb was sufficient to reduce total tree biomass by 7 per cent compared with pre-industrial levels. The ozone critical levels for (semi-)natural vegetation can be considered the most uncertain. This is mainly due to the complexity of these ecosystems, with uncertainty increasing from productive grasslands to low input grasslands and being highest for natural ecosystems. The uncertainties at present associated with the flux-based approach for (semi-)natural vegetation include variability of the maximum stomatal conductance, genotypic variability of individual species, diversity of communities, soil moisture modelling, competition and management effects.

C. Links with biodiversity

4. Although different sensitivities to ozone have been identified for plant species and plant communities (see ECE/EB.AIR/WG.1/2007/9), there is hardly any field-based evidence of the impacts of ozone on biodiversity, as little field-based research has been done yet. In the field, impacts of ozone on vegetation will be difficult to disentangle from other drivers of change, such as nitrogen pollution, climate change and changes in land use and management. Legumes (i.e., nitrogen fixing forbs) have been identified as a particularly sensitive plant group, hence it is expected that their abundance will decline in an atmosphere with rising ozone background concentrations.

D. Trends in selected monitored/modelled parameters

5. Evidence of widespread ozone damage to vegetation in Europe was recently reviewed (see ECE/EB.AIR/WG.1/2008/9). At the local scale, there was evidence of higher ozone damage in years with higher ozone concentrations (e.g., in 2003 and 2006) in regions of Europe where climatic conditions were conducive to high ozone fluxes. However, the timescale and density of data points were insufficient to allow any long-term trends related, for example, to the changing ozone profile (lower peaks, increasing background), to be identified. In general, there was more ozone damage to vegetation in areas with the highest ozone fluxes and flux-based critical level exceedance (parts of Central and Southern Europe), but damage was also observed in areas of northern Europe where flux-based critical levels were exceeded but concentration-based critical levels were not exceeded.

6. The European moss survey showed that the highest nitrogen concentrations in mosses in 2005–2006 were found in Central and Eastern Europe and the lowest concentrations in north-western Europe. No temporal trends for nitrogen concentrations in mosses are available yet. In general, the highest heavy metal concentrations in mosses in 2005–2006 were found in parts of Eastern Europe and Belgium. Europe-wide concentrations of arsenic, cadmium, iron, lead and vanadium declined the most since 1990 (by 45-72 per cent), the decline in the concentration of copper, nickel and zinc was intermediate (20-30 per cent), and there were no significant reductions found for chromium (2 per cent) and mercury (12 per cent since 1995).

III. Nutrient nitrogen

7. The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) Task Force agreed to conduct the next European survey of nitrogen concentrations in naturally occurring mosses in 2010–2011. So far, 7 out of 18 countries had definitely confirmed their participation.

IV. Ozone

8. Data were submitted from 15 sites in nine countries for the ozone biomonitoring experiment with beans in 2009. Higher ozone leaf injury scores were often observed in the ozone-sensitive, as compared with the ozone-resistant, variety of French dwarf bean, leading to a reduction in the relative bean yield in the ozone-sensitive variety. The extent of leaf injury and the relative bean yield of the sensitive variety were not clearly related to the accumulated ozone concentration above a threshold of 40 ppb (AOT40). It was decided to develop an ozone stomatal flux model for beans to establish whether robust flux-effect relationships could be developed in the future.

9. Current ambient ozone concentrations in the Mediterranean area induced negative impacts on the production and quality of many agricultural and horticultural crop species of economic importance. Reductions in yield have been observed in, for example, wheat, potato, tomato, beans, watermelon and lettuce. Moreover, effects on food quality like reduced sugar concentration and delayed fruit ripeness in tomato and watermelon caused a decrease in their marketable value. In some cases, high ozone episodes caused high economic losses due to the appearance of visible injury on leafy salad crops. Ambient ozone concentrations also caused visible leaf damage and effects on growth and plant physiology in some evergreen forest species common in the Mediterranean area, such as Holm oak, carob tree and Aleppo pine. Furthermore, foliar symptoms and physiological effects were observed in ozone-sensitive deciduous tree species such as oak, poplar or maple. There is scarce information on the ozone sensitivity of the Mediterranean herbaceous plant communities. Ozone pollution reduced flower and seed production and forage quality in sensitive annual legume species growing in Dehesa grassland, a characteristic ecosystem covering extensive areas included in the European Union’s Natura 2000 network. Despite the high ozone concentrations frequently experienced in Mediterranean areas, observed ozone impacts were often less severe than expected due to interactions with other environmental stresses such as drought. This supports the further development of the flux-based approach, with specific parameterizations of the flux model being required for Mediterranean areas. Flux-based ozone critical levels for Mediterranean vegetation are still subject to considerable uncertainties in terms of dry deposition modelling and dose-response relationship derivation.

10. In recent years, climate-specific ozone flux modelling methods were developed for crops and forest tree species, resulting in the development of statistically robust flux-

response relationships from which it has been possible to derive critical levels for ozone for vegetation at the European scale (see ECE/EB.AIR/WG.1/2010/13). In this method, climate-specific stomatal flux data were pooled and it was assumed that only the variation in stomatal flux by climatic conditions determined species response to ozone — i.e., climatic and species-specific effects on the detoxification of ozone were not taken into account. Care should be taken when applying the parameterizations for European-scale integrated risk assessment to the national scale, for which the application of non-pooled climate-specific stomatal flux data might be more appropriate. As yet, no climate region-specific parameterizations are available for (semi-)natural vegetation.

11. Ten new and/or revised flux-based critical levels of ozone for vegetation were agreed in a related workshop and follow-on discussions (see ECE/EB.AIR/WG.1/2010/13). In addition, policy-relevant indicators for integrated assessment modelling to protect food supplies and quality, ecosystem services such as carbon storage and prevention of soil erosion, flooding and avalanches and vitality and quality of (semi-) natural grasslands were derived.

V. Heavy metals

12. The ICP Vegetation Task Force agreed to conduct the next European survey on heavy metal concentrations in naturally occurring mosses in 2010–2011. So far, 14 out of 30 countries have definitely confirmed their participation.

13. Previous analysis at the European scale showed that cadmium and lead concentrations in mosses were primarily determined by the rate of atmospheric deposition of those metals as modelled by the Convention's Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants (EMEP) (see ECE/EB.AIR/WG.1/2009/9); this was not the case for mercury. Further analysis for cadmium and lead revealed country-specific correlations between their concentration in mosses and EMEP-modelled atmospheric deposition. The correlation coefficients (r) ranged from highly positive (r = 0.88) to slightly negative (r = -0.28). Factors contributing to the observed range in correlation coefficients included: (i) the comparison of site-specific heavy metal concentrations in mosses with modelled deposition averaged in the 50 km x 50 km EMEP grid; (ii) moss data included input from the local pollution source, whereas the EMEP model aims to model long-range transboundary air pollution; (iii) uncertainties in the moss and modelled EMEP deposition data; (iv) some limitations identified in the application of mosses as biomonitors of atmospheric heavy metal deposition.