Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Air Pollution and Vegetation

ICP Vegetation

Annual Report 2013/2014

Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

Air Pollution and Vegetation

ICP Vegetation[1] Annual Report 2013/2014

Harry Harmens[1], Gina Mills[1], Felicity Hayes[1], Katrina Sharps[1], Marina Frontasyeva[2], and the participants of the ICP Vegetation

[1] ICP Vegetation Programme Coordination Centre, Centre for Ecology and Hydrology, Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW, UK
Tel: + 44 (0) 1248 374500, Fax: + 44 (0) 1248 362133, Email: hh@ceh.ac.uk
http://icpvegetation.ceh.ac.uk

[2] Moss Survey Coordination Centre, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Str. Joliot-Curie, 6, Dubna, Moscow Region, Russian Federation.
Tel: +7 49621 65609, Fax: +7 49621 65085, Email: mfrontasyeva@jinr.ru
http://flnp.jinr.ru/naa

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[1] International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops.

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Finallly, we wish to thank all of the ICP Vegetation participants for their continued contributions to the programme.

With sadness we notify that Lilyana Yurukova (IBER - Base 3 - ex-Institute of Botany, Bulgarian Academy of Sciences, Sofia, Bulgaria) has passed away in August 2014. Her commitment and contribution to the European moss survey will surely be missed.

Front cover photo: Shutterstock, UK

Executive Summary

Background

The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) was established in 1987. It is led by the UK and has its Programme Coordination Centre at the Centre for Ecology and Hydrology (CEH) in Bangor. It is one of seven ICPs and Task Forces that report to the Working Group on Effects (WGE) of the Convention on Long-range Transboundary Air Pollution (LRTAP Convention) on the effects of atmospheric pollutants on different components of the environment (e.g. forests, fresh waters, materials) and health in Europe and North-America. Today, the ICP Vegetation comprises an enthusiastic group of over 200 scientists from 42 countries, including scientists from outside the UNECE region. An overview of contributions to the WGE workplan and other research activities in the year 2013/14 is provided in this report.

27th ICP Vegetation Task Force meeting

The Programme Coordination Centre organised the 27th ICP Vegetation Task Force meeting, 28 – 30 January 2014 in Paris, France. The meeting was hosted by the French Environment and Energy Management Agency (ADEME), in collaboration with AgroParisTech, INRA, Muséum national d'Histoire naturelle (MNHN) and Université Paris-Est Creteil (UPEC). The meeting was attended by 84 experts from 22 countries, including 19 Parties to the LTRAP Convention and guests from Algeria, Egypt and Japan. The first day of the meeting was a one-day workshop on the quantification of ozone impacts on vegetation, including a review of existing flux-effect relationships for ozone impacts and ozone critical levels for vegetation.The Task Force discussed the progress with the workplan items for 2014 and updated the medium-term workplan for 2015 - 2017 for the air pollutants ozone, heavy metals, nutrient nitrogen and persistent organic pollutants (POPs). The Task Force acknowledged and encouraged further fruitful collaborations with other Convention bodies, particularly EMEP, and encouraged further development of activities in Eastern Europe, Caucasus and Central Asia (EECCA) and outreach activities to other regions in the world. A book of abstracts and the minutes of the 27th Task Force meeting are available from the ICP Vegetation web site (http://icpvegetation.ceh.ac.uk).

Reporting to the Convention and other publications

In addition to this report, the ICP Vegetation Programme Coordination Centre has provided a technical report on 'Effects of air pollution on natural vegetation and crops' (ECE/EB.AIR/WG.1/2014/8) and on 'Air pollution: Deposition to and impacts on vegetation in (South-) East Europe, Caucasus, Central and South-East Asia' (ECE/EB.AIR/WG.1/2014/13). The latter was also published as a glossy report and translated into Russian. ICP Vegetation also contributed to the joint report (ECE/EB.AIR/WG.1/2014/3) of the WGE. The ICP Vegetation Programme Coordination Centre published a glossy brochure titled 'Have you seen these ozone injury symptoms?', containing images of ozone-induced leaf injury on vegetation. This brochure was produced in collaboration with the Expert Panel on Ambient Air Quality of the ICP Forests and was translated into Russian too. Four scientific papers were published in the last year.

Air pollution: Deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia

Increased ratification of the Protocols of the Convention on Long-range Transboundary Air Pollution (LRTAP) was identified as a high priority in the long-term strategy of the Convention (EB Decision 2010/18). Increased ratification and full implementation of air pollution abatement policies is particularly desirable for countries of Eastern Europe, the Caucasus and Central Asia (EECCA) and South-Eastern Europe (SEE). The ICP Vegetation has reviewed current knowledge on the deposition of air pollutants to and their impacts on vegetation in EECCA and SEE countries. As an outreach activity to Asia, current knowledge on this subject was also reviewed for the Malé Declaration countries in South-East Asia. The review focussed on the air pollutants nitrogen, ozone, heavy metals, POPs (EECCA/SEE) and aerosols (South-East Asia) of which black carbon is a component and the review discussed their impacts on vegetation. There is a lack of monitoring data regarding the deposition to and impacts of air pollutants on vegetation in EECCA/SEE countries and South-East Asia. It would be desirable to further enlarge coordinated networks to measure air concentrations and depositions of air pollutants, i.e. to extend the EMEP monitoring network in the EECCA/SEE region and establish a similar network in South-East Asia, for example by extending the Acid Deposition Monitoring Network in East Asia (EANET) by including other regions and more pollutants. More measurement data are urgently needed to validate model outputs regarding the concentrations, deposition and associated risk for impacts of air pollutants on vegetation. The successful implementation of air pollution abatement policies in many other parts of Europe has highlighted the slower progress made with some of the air pollution abatement in the Eastern Europe, the Caucasus, Central and South-East Asia. Air pollution is a main concern in Asia due to enhanced industrialisation, which is directly linked to strong economic growth in recent decades.

Recent developments of the flux-based approach for setting critical levels of ozone for vegetation

The Task Force of the ICP Vegetation adopted a simplified flux model, response function and associated critical level for crop species (based on the full flux model for wheat) for application in integrated assessment modelling at the European scale. These are provided for use in scenario analysis and optimisation runs within the GAINS (**G**reenhouse Gas and **A**ir Pollution **In**teractions and **S**ynergies) model to provide an indication of potential effects on wheat yield under non-limiting water availability. The parameterisation for stomatal flux should be based on two parameterisations for cereals: i) Northern and Central Europe; ii) Mediterranean areas. As the modifying effect of soil moisture on stomatal conductance is not included in the simplified crop flux model then this method indicates the risk of damage under a worst case scenario where soil moisture is not limiting to flux. However, it is noted that even using the Mediterranean parameterisation, this approach may over-estimate risk of damage for non-irrigated crops in dry climates because of the lack of inclusion of a soil moisture parameterisation.

New parameterisations of the ozone stomatal flux model were published for bread and durum wheat in Mediterranean areas. In addition, the Task Force adopted new flux parameterisations for grapevine, maize, soybean, sunflower and poplar. All these recent developments of the flux-based approach have been included in a recent revision of the Modelling and Mapping Manual of the LRTAP Convention (Chapter 3: Mapping critical levels for vegetation).

Supporting evidence for ozone impacts on vegetation

Ozone biomonitoring using bean

In 2013, participation in the ozone biomonitoring experiment with bean (*Phaseolus vulgaris*) was limited to Algeria, China (3 sites), Croatia, Italy, Niger, Pakistan, Poland and Ukraine, of which many participated for the first time. Visible leaf injury attributed to ozone was observed in China, Italy, Pakistan and Poland. In China, visible leaf injury was also apparent on local bean cultivars growing in/near Beijing. Ozone concentrations were higher in the suburbs of Beijing than in central Beijing. In central Beijing and the suburbs there was a large reduction (>50%) in pod number and seed yield of the sensitive compared to the resistant variety, but there was a smaller reduction at the site in a more rural region with much lower ozone concentrations.

Smart-phone application for recording incidences of ozone-induced leaf injury

Using smart-phone technology for i-phones and android phones, and a web-based recording methodology, ICP Vegetation has developed a new way of recording incidences of ozone injury in the field. The smart phone App allows participants to upload photographs of ozone injury direct from the field together with the coordinates for the location where the injury was detected. App users are taken through a short series of questions, with answers selected from drop-down menus. The broad vegetation types of the damaged species (from Crop, Tree, Grassland, Heathland, Wetland and Coastal) and the species name can be chosen from a list. Information on the symptoms of ozone injury (including the colour, location on the leaf and age of damaged leaves) is also requested from the user. Questions designed to assist with quality assurance are also included. The App contains an

'Ozone information' section, which includes details of the key symptoms of ozone injury, and other causes of leaf damage that may be mistakenly recorded as ozone injury. There is an 'Examples of ozone injury' page, containing photos of ozone injury on many of the species included in the App species list. The App is being tested in 2014 by ozone experts and is scheduled for release to a wider audience in 2015 (see http://icpvegetation.ceh.ac.uk/record/index).

Contributions to the WGE common workplan

The ICP Vegetation has also contributed to the following common workplan items of the WGE:

- Further implementation of Guidelines on Reporting of Air Pollution Effects. The ICP Vegetation continued to monitor and model deposition to and impacts on vegetation for the air pollutants ozone, heavy metals, nitrogen and POPs.
- Enhanced involvement of EECCA/SEE countries in the Eastern Europe, the Caucasus and Central Asia and cooperation with activities outside the Air Convention. In 2014, ICP Vegetation transferred the coordination of the European moss survey (i.e., monitoring heavy metals, nitrogen and persistent organic pollutant (POP) concentrations in mosses every five years) to the Russian Federation. The new Moss Survey Coordination Centre, at the Institute for Joint Nuclear Research in Dubna (http://flnp.jinr.ru/naa), is negotiating for or has reached agreement on the participation of several countries in Eastern Europe, the Caucasus and Central Asia and selected other Asian countries. The updated Moss Monitoring Manual was translated into Russian. The next moss survey will be conducted in 2015/16.
- Cooperation with programmes and activities outside the region. ICP Vegetation co-organised the 'Ozone and Plants' Conference in Beijing, China, May 2014, in collaboration with the Chinese Academy of Sciences and the International Union of Forest Research Organizations (IUFRO). ICP Vegetation is keen to continue its collaboration with the Chinese Academy of Sciences and IUFRO in the future and to stimulate further outreach activities outside the ECE region.

Future activities of the ICP Vegetation

The medium-term workplan for 2015 – 2017 was adopted at the 27th Task Force Meeting of the ICP Vegetation (Paris, France, 28 - 30 January, 2014). Ongoing annual activities include i) report on supporting evidence for ozone impacts on vegetation, ii) report on preparations and progress with the moss survey 2015/16, and iii) contributions to common workplan items of the WGE.

New activities include:

2015:

- Report on the implications of rising background ozone for vegetation in Europe;
- Report on the interacting effects of co-occurring pollutants (ozone and nitrogen) and climatic stresses on vegetation.

Tentatively for 2016:

- Update report on field-based evidence of ozone impacts on vegetation;
- Report on ozone impacts on biodiversity;
- Ozone critical levels workshop.

Tentatively for 2017:

- Report on revised ozone risk assessments methods;
- Revision of Chapter 3 of the Modelling and Mapping Manual;
- Report of the European moss survey 2015/16.

Contents

1 Introduction

1.1 Background

The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) was established in 1987, initially with the aim to assess the impacts of air pollutants on crops, but in later years also on (semi-)natural vegetation. The ICP Vegetation is led by the UK and has its Programme Coordination Centre at the Centre for Ecology and Hydrology (CEH) in Bangor. The ICP Vegetation is one of seven ICPs and Task Forces that report to the Working Group on Effects (WGE) of the Convention on Long-range Transboundary Air Pollution (LRTAP Convention) on the effects of atmospheric pollutants on different components of the environment (e.g. forests, fresh waters, materials) and health in Europe and North-America. The Convention provides the essential framework for controlling and reducing damage to human health and the environment caused by transboundary air pollution. So far, eight international Protocols have been drafted by the Convention to deal with major long-range air pollution problems. ICP Vegetation focuses on the following air pollution problems: quantifying the risks to vegetation posed by ozone pollution and the atmospheric deposition of heavy metals, nitrogen and persistent organic pollutants (POPs) to vegetation. In addition, the ICP Vegetation studies the interactive impacts of air pollutants (e.g. ozone and nitrogen) on vegetation in a changing climate.

The ICP Vegetation comprises an enthusiastic group of over 200 scientists from 42 countries (**Table 1.1**), including scientists from outside the UNECE region as the ICP Vegetation stimulates outreach activities to other regions in the world. The ICP Vegetation is also keen to enhance participation of countries in South-East Europe (SEE) and in Eastern Europe, Caucasus and Central Asia (EECCA). Hence, earlier this year ICP Vegetation reviewed the deposition to and impacts on vegetation in these regions, and also included South-East Asia in the review. In addition, the ICP Vegetation established a new Moss Survey Coordination Centre at the Joint Institute for Nuclear Research, Dubna, Russian Federation. The head of the new Moss Survey Coordination Centre is Marina Frontasyeva, who also assisted the ICP Vegetation Programme Coordination Centre with the translation of various documents into Russian. The contact details for lead scientists for each group are included in Annex 1. In many countries, several other scientists (too numerous to mention individually) also contribute to the biomonitoring programmes, analysis, modelling and data synthesis procedures of the ICP Vegetation.

Table 1.1 Countries[a] participating in the ICP Vegetation; in italics: not a Party to the LRTAP Convention.

Albania	France	Poland
Algeria	FYR of Macedonia	Romania
Austria	Germany	Russian Federation
Belarus	Greece	Serbia
Belgium	Iceland	Slovakia
Bulgaria	*India*	Slovenia
China	Italy	*South Africa*
Croatia	*Japan*	Spain
Cuba	Latvia	Sweden
Czech Republic	Lithuania	Switzerland
Denmark	Netherlands	Turkey
Egypt	*Niger*	Ukraine
Estonia	Norway	United Kingdom
Finland	*Pakistan*	USA

[a] Kosovo (United Nations administered territory, Security Council resolution 1244 (1999)) also participates.

1.2 Air pollution problems addressed by the ICP Vegetation

1.2.1 Ozone

Ozone is a naturally occurring chemical present in both the stratosphere (in the 'ozone layer', 10 – 40 km above the earth) and the troposphere (0 – 10 km above the earth). Additional photochemical reactions involving NO_x, carbon monoxide and non-methane volatile organic compounds (NMVOCs) released due to anthropogenic emissions (especially from vehicle sources) increase the concentration of ozone in the troposphere. These emissions have caused a steady rise in the background ozone concentrations in Europe and the USA since the 1950s (Royal Society, 2008). Superimposed on the background tropospheric ozone are ozone episodes where elevated ozone concentrations in excess of 50-60 ppb can last for several days. Ozone episodes can cause short-term responses in plants such as the development of visible leaf injury (fine bronze or pale yellow specks on the upper surface of leaves) or reductions in photosynthesis. If episodes are frequent, longer-term responses such as reductions in growth and yield and early die-back can occur.

The ozone sub-group of the ICP Vegetation contributes models, state of knowledge reports and information to the LRTAP Convention on the impacts of ambient ozone on vegetation; dose-response relationships for species and vegetation types; ozone fluxes, vegetation characteristics and stomatal conductance; flux modelling methods and the derivation of critical levels and risk assessment for policy application (Mills et al., 2011b; LRTAP Convention, 2014).

1.2.2 Heavy metals, nitrogen and persistent organic pollutants (POPs)

Concern over the accumulation of heavy metals in ecosystems and their impacts on the environment and human health, increased during the 1980s and 1990s. Currently some of the most significant sources include metals industry, other manufacturing industries and construction, electricity and heat production, road transportation and petroleum refining. Whereas agricultural activities are the main source for atmospheric ammonia, fossil fuel combustion (industry, transport) is the main source for nitrogen oxides in the atmosphere. Sources and effects of atmospheric nitrogen deposition have been reviewed recently by Sutton et al. (2011). Reactive nitrogen poses a key threat to water, air and soil quality, ecosystems and biodiversity and greenhouse gas balance. Too much nitrogen harms the environment and the economy (Sutton et al., 2011). POPs are organic substances that possess toxic and/or carcinogenic characteristics. They degrade very slowly in the environment, bioaccumulate in the food chain and like heavy metals and nitrogen are prone to long-range transboundary atmospheric transport and deposition. Anthropogenic sources of POPs include waste incineration, industrial production and application (such as pesticides, flame retardants, coolant fluids).

Since 2000/1, the ICP Vegetation coordinates the European moss survey on heavy metals. It involves the collection of naturally-occurring mosses and determination of their heavy metal concentration at five-year intervals. European surveys have taken place every five years since 1990, and the latest survey was conducted in 2010/11. Mosses were collected at thousands of sites across Europe and their heavy metal (since 1990; Harmens et al., 2010, 2013c), nitrogen (since 2005; Harmens et al., 2011, 2013c) and POPs concentration (pilot study in 2010; Harmens et al., 2013a,b) were determined. The next survey is planned for 2015/16 and will be extended into Asia.

Ectohydric mosses do not have a vascular root system or a waxy cuticle layer and therefore obtain most trace elements (e.g. heavy metals), nutrients (e.g. nitrogen) and organic pollutants directly from atmospheric (wet and dry) deposition. The analysis of their concentrations in mosses provides a time-integrated measure of atmospheric deposition to terrestrial systems (Harmens et al., 2012; Holy et al., 2010; Schröder et al., 2010a,b). It is easier and cheaper than conventional precipitation analysis as it avoids the need for deploying large numbers of deposition collectors with an associated long-term programme of routine sample collection and analysis. Hence, the moss survey provides a complementary method to assess spatial patterns and temporal trends of atmospheric deposition to vegetation (based on monitoring in the field) and to identify areas at risk from air pollution at a high spatial resolution.

1.3 ICP Vegetation workplan for 2014

The Executive Body of the LRTAP Convention agreed on a workplan for 2014 and 2015 at its 32nd meeting in December 2013 (see ECE/EB.AIR/122/Add.2). Here we will report on the workplan items for the ICP Vegetation for 2014:

- Evaluate effects on (semi-)natural vegetation and crops due to the impact of:
  - (a) Tropospheric ozone;
  - (b) Air pollution in Eastern and South-Eastern Europe, the Caucasus and Central and South-East Asia;
- Further development of the flux-based approach for setting critical levels of ground-level ozone for vegetation;
- Carry out preparatory work for the European moss survey 2015/16.

In addition, the ICP Vegetation was requested to report on the following common workplan items of the WGE:

- Setting priorities for monitoring and collection of other data in view of policy needs and given financial constraints;
- Further implementation of the Guidelines on Reporting of Monitoring and Modelling of Air Pollution Effects;
- Enhance the involvement of countries in Eastern and South-Eastern Europe, the Caucasus and Central Asia, and on cooperation with activities outside the Convention;
- Cooperate with programmes and activities outside the ECE region;
- Prepare an annual report to the Executive Body for its meeting in 2014 on recent findings under Working Group on Effects and their implications for policy.

In Chapter 2, general coordination activities of the ICP Vegetation are described, including the 27th ICP Vegetation Task Force meeting and dissemination of results. In Chapter 3, Air pollution deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia are described and Chapter 4 reports on further development of the flux-based approach for setting critical levels of ground-level ozone for vegetation. Progress with the preparations for the European moss survey 2015/16, other ICP Vegetation workplan items and common workplan items of the WGE are discussed in Chapter 5. Finally, planned activities of the ICP Vegetation for 2015 – 2017 are described in Chapter 6.

2 Coordination activities

2.1 Annual Task Force meeting

The Programme Coordination Centre organised the 27th ICP Vegetation Task Force meeting, 28 – 30 January 2014 in Paris, France. The meeting was hosted by the French Environment and Energy Management Agency (ADEME), in collaboration with AgroParisTech, INRA, Muséum national d'Histoire naturelle (MNHN) and Université Paris-Est Creteil (UPEC). The meeting was attended by 84 experts from 22 countries, including 19 Parties to the LTRAP Convention and guests from Algeria, Egypt and Japan (**Figure 2.1**). The first day of the meeting was a one-day workshop on the quantification of ozone impacts on vegetation, including a review of existing flux-effect relationships for ozone impacts and ozone critical levels for vegetation.

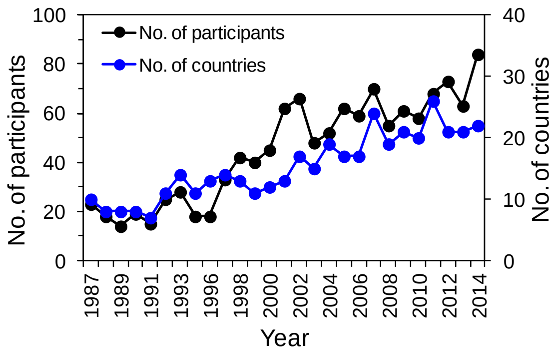

Figure 2.1 Participation in ICP Vegetation Task Force meetings since 1987.

Decisions and recommendations regarding ozone flux-effect relationships, critical levels and the flux-based methodology are described in more detail in Chapter 4. The Task Force also encouraged further epidemiological studies to enable further validation of ozone flux-effect relationships in the field (Braun et al., 2014) and recommended to compare EMEP model outputs for ozone with national monitoring and modelling data to assess the robustness of the EMEP model at the national scale. The Task Force adopted transfer of the coordination of the European moss survey from the ICP Vegetation Coordination Centre at CEH Bangor, UK, to the Joint Institute for Nuclear Research (lead coordinator: Marina Frontasyeva), Dubna, Russian Federation, with the aim to enhance participation from countries in Eastern Europe, Caucasus and Central Asia (EECCA) and South-East Europe (SEE) and encourage outreach to Asia. The next European moss survey will be conducted in 2015/16 and the survey will remain a core activity of the ICP Vegetation. A book of abstracts and the minutes of the 27th Task Force meeting are available from the ICP Vegetation web site (http://icpvegetation.ceh.ac.uk). The Task Force also discussed the progress with the workplan items for 2014 (see Section 1.3) and updated the medium-term workplan for 2015 - 2017 (see Chapter 6) for the air pollutants ozone, heavy metals, nutrient nitrogen and POPs.

The Task Force acknowledged and encouraged further fruitful collaborations with the bodies and centres under the Working Group on Effect and the Steering Body to EMEP, particularly EMEP/MSC-West, EMEP/MSC-East, the Task Force on Integrated Assessment Modelling and the Task Force on the Hemispheric Transport of Air Pollution, and bodies under the Working Group of Strategies and Review, in particular the Task Force on Reactive Nitrogen. For example, collaborations are currently taking place in the European Framework 7 project 'ECLAIRE (Effect of Climate Change on Air Pollution and Response Strategies for European Ecosystems, http://www.eclaire-fp7.eu), which includes contributions from several ICP Vegetation participants and other LRTAP Convention bodies. In addition, the Task Force encouraged further development of outreach activities to other regions in the world (see also Chapter 3).

The **28th Task Force meeting** will be held in Rome, Italy from 3 - 5 February 2015.

2.2 Other meetings

ICP Vegetation co-organized the 'Ozone and Plants' Conference in Beijing, China, 18 - 21 May, 2014, in collaboration with the Chinese Academy of Sciences and the International Union of Forest Research Organizations (IUFRO; http://www.iufro.org/science/divisions/division-7/70000/70100/). One session at the conference was organized in collaboration with the Task Force on Hemispheric Transport of Air Pollution. The hemispheric nature of ozone pollution requires further collaboration with the Task Force regarding impact assessments on vegetation and feedbacks to the climate, applying agreed air pollution abatement and climate scenarios globally. The conference was attended by 102 experts from 17 countries with a total of 48 oral presentations and 40 posters. Ozone was confirmed to be a serious air pollution problem - particularly in Asia - adversely affecting crops, forest trees and ecosystem health.

Recommendations resulting from the conference were the need to:

- Set-up coordinated surface ozone monitoring programmes across the world to validate modelled surface ozone concentrations and deposition;
- Collate further existing field-based evidence for the impacts of ambient ozone on vegetation;
- Establish more free-air ozone exposure facilities to quantify the adverse impact of ozone on vegetation under field conditions;
- Further develop ozone dose-response relationships and critical levels for vegetation, in particular under Asian conditions and using Asian species and cultivars;
- Include sensitivity for ozone in crop breeding programmes to mitigate the threat of ozone pollution to food security;
- Communicate to stakeholders - such as crop breeders, farmers and policy makers - the severity of the threat of ozone pollution to food security, carbon sequestration and other ecosystem services affecting human wellbeing.

The chair of the ICP Vegetation and other members of ICP Vegetation also gave keynote presentations at the 9th Air Pollution and Global Change Symposium 'Plants and the changing environment' in Monterey Bay, California, USA, 8 – 12 June, 2014. The meeting strengthened the collaboration between ozone scientists in Europe and the USA.

2.3 Reports to the LRTAP Convention

The ICP Vegetation Programme Coordination Centre has reported progress with the 2014 workplan items in the following documents for the 33nd session of the WGE, 17 - 19 September 2014, Geneva, Switzerland (http://www.unece.org/env/clrtap/wge33.html):

- ECE/EB.AIR/WG.1/2014/3: Joint report of the ICPs, Task Force on Health and Joint Expert Group on Dynamic Modelling;
- ECE/EB.AIR/WG.1/2014/8: Effects of air pollution on natural vegetation and crops;
- ECE/EB.AIR/WG.1/2014/13: Air pollution: Deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central and South-East Asia (see Chapter 3).

In addition, the Programme Coordination Centre for the ICP Vegetation has published:

- A glossy report on 'Air pollution: Deposition to and impacts on vegetation in (South-) East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia' (Harmens and Mills, Eds, 2014), see Chapter 3;
- The current annual report on line;
- A glossy brochure titled 'Have you seen these ozone injury symptoms?', containing images of ozone-induced leaf injury on vegetation. This brochure was produced in collaboration with the Expert Panel on Ambient Air Quality of the ICP Forests.

The ICP Vegetation has also contributed data to the following EMEP reports:

- EMEP Status Report 2/2014: Heavy metals: Transboundary pollution of the environment.
- EMEP Status Report 3/2014: Persistent organic pollutants in the environment.

At the 32nd session of the Executive Body of the LRTAP Convention, 9 – 13 December, 2013, Geneva, Switzerland, the chair of the ICP Vegetation gave a presentation on the WGE report on 'Benefits of air pollution control for biodiversity and ecosystem services' (ECE/EB.AIR/WG.1/2013/14). At the 52nd session of the Working Group on Strategies and Review, 30 June – 3 July, 2014, Geneva, Switzerland, the chair of the ICP Vegetation gave a presentation on the new ICP Vegetation smart-phone application for recording ozone-induced leaf injury (http://icpvegetation.ceh.ac.uk/record/index; see Chapter 5).

2.4 Scientific papers

The following papers have been published:

Harmens, H., Schnyder, E., Thöni, L., Cooper, D.M., Mills, G., Leblond, S., Mohr, K., Poikolainen, J., Santamaria, J., Skudnik, M., Zechmeister, H.G., Lindroos, A.-J., Hanus-Illnar, A. (2014). Relationship between site-specific nitrogen concentrations in mosses and measured wet bulk atmospheric nitrogen deposition across Europe. Environmental Pollution 194: 50 - 59.

Pleijel, H., Danielsson, H., Simpson, D., Mills, G. (2014). Have ozone effects on carbon sequestration been over-estimated? A new biomass response function for wheat. Biogeosciences 11 (16): 4521 – 4528 .

Schröder, W., Pesch, R., Schönrock, S., Harmens, H., Mills, G., Fagerli, H. (2014). Mapping correlations between nitrogen concentrations in atmospheric deposition and mosses for natural landscapes in Europe. Ecological Indicators 36: 563-571.

Simpson, D., Arneth, A., Mills, G., Solberg, S., Uddling, J. (2014). Ozone – the persistent menace: interactions with the N cycle and climate change. Current Opinion in Environmental Sustainability 9-10: 9-19.

3 Air pollution: Deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia

In this chapter we provide an extended executive summary of the full report, for further details and references we refer to the full report (Harmens and Mills, 2014).

3.1 Introduction

Increased ratification of the Protocols of the Convention on Long-range Transboundary Air Pollution (LRTAP) was identified as a high priority in the long-term strategy of the Convention (EB Decision 2010/18). Increased ratification and full implementation of air pollution abatement policies is particularly desirable for countries of Eastern Europe, the Caucasus and Central Asia (EECCA) and South-Eastern Europe (SEE). Hence, scientific activities within the Convention will need to involve these countries. The ICP Vegetation has reviewed current knowledge on the deposition of air pollutants to and their impacts on vegetation in EECCA (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan) and SEE countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, Macedonia, Montenegro, Romania, Serbia, Slovenia and Turkey). As an outreach activity to Asia, current knowledge on this subject was also reviewed for the Malé Declaration countries in South-East Asia (Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan and Sri Lanka). Air pollution is a main concern in Asia due to enhanced industrialisation, which is directly linked to strong economic growth in recent decades.

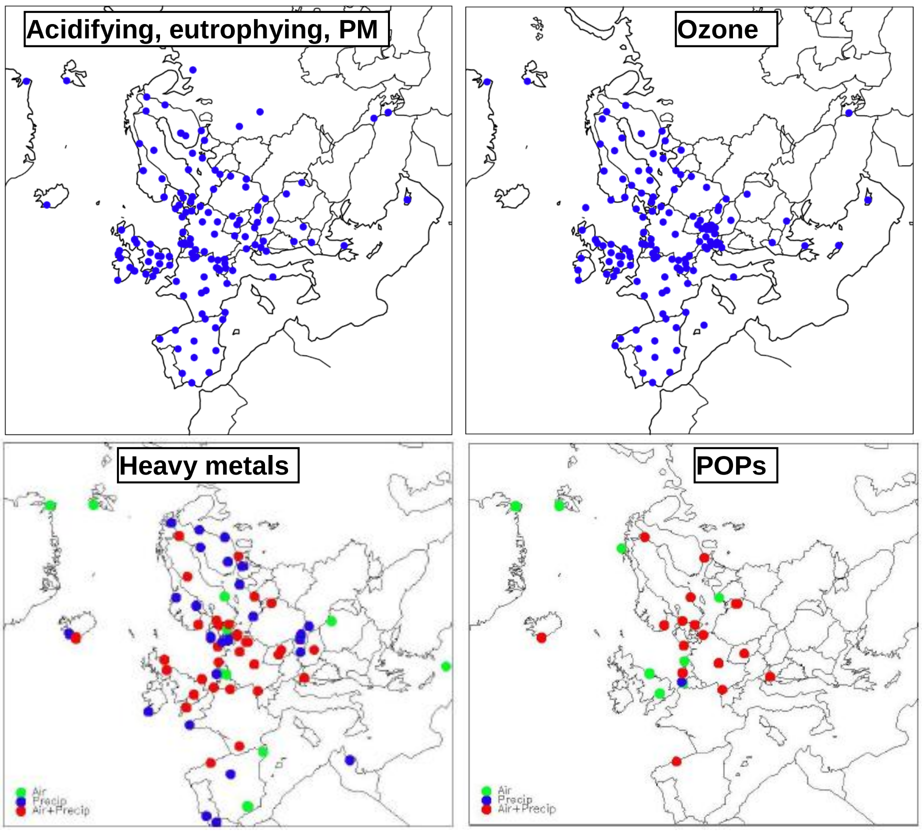

Figure 3.1 EMEP monitoring network for acidifying, eutrophying compounds and particulate matter (PM; top left; excluding ozone only measurements sites), ozone (top right), heavy metals (bottom, left; note: Cyprus is misplaced in the map to fit inside the map) and persistent organic pollutants (POPs; bottom, right) operational in 2011. Sources: EMEP/MSC-West and East.

In these regions, there is generally a lack of an extensive network of monitoring stations to assess the magnitude of air concentrations and depositions of pollutants (**Figure 3.1**). In addition, emission inventories are often incomplete or not reported at all for some pollutants, which makes it difficult to validate atmospheric transport models for these regions. Furthermore, there is often a lack of coordinated monitoring networks to assess the impacts of air pollution on vegetation. Hence, the risk of adverse impacts on vegetation often has to be assessed using atmospheric transport models in conjunction with metrics developed to compute the risk of air pollution impacts on vegetation, such as critical loads and levels. Here we have focussed on the following air pollutants: nitrogen, ozone, heavy metals; persistent organic pollutants (POPs) were only included for EECCA/SEE countries and aerosols, including black carbon as a component, only for South-East Asia. Country-specific reports were included for Albania, Croatia, Greece, Macedonia, Romania, Russian Federation, Serbia and Slovenia; in addition a country report for Egypt was included as an outreach activity.

3.2 Nitrogen

Critical load exceedances for nutrient nitrogen are only available for a limited number of EECCA countries. Compared with Western and Central Europe, available computed critical load exceedances for nitrogen have historically been lower in SEE and large areas of the EECCA region (Hettelingh et al., 2012), particularly the northern part, and this was also the case in 2010 (**Figure 3.2**). However, the critical load is expected to still be exceeded in large areas in 2020 with improvements since 2005 generally being lower than in Western and Central Europe, particularly in the EECCA region.

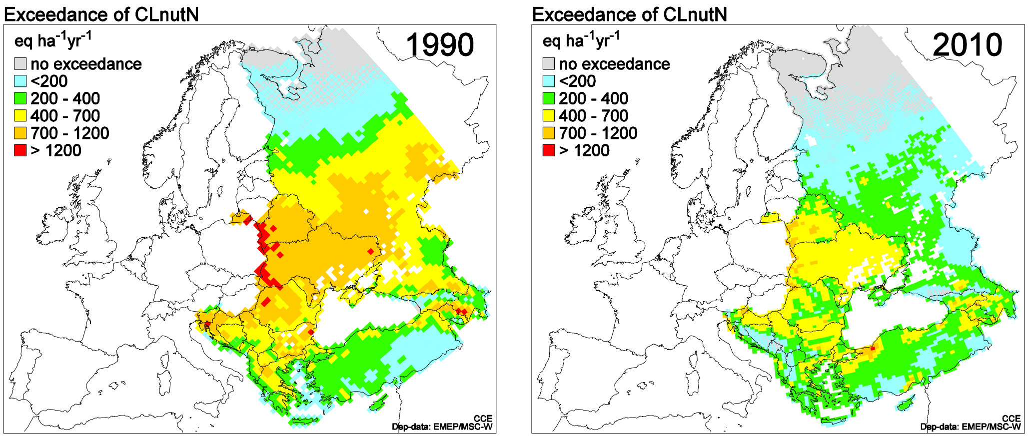

Figure 3.2 Areas in Eastern Europe where critical loads for eutrophication are exceeded by nutrient nitrogen deposition in 1990 (left) and 2010 (right). Note: The 1990 map is on the EMEP 50 km × 50 km grid whereas the 2010 map is on the 0.5 × 0.25 degree longitude – latitude grid using the latest EMEP model output; the critical loads are from the 2011/12 data base. Source: Coordination Centre for Effects.

Nitrogen concentrations in mosses in 2005 and 2010 were only reported in Bulgaria, Croatia, Macedonia, Slovenia and Turkey (2005 only) and not in any of the EECCA countries (Harmens et al., 2008, 2011, 2013c). Nitrogen concentrations in mosses were found to be intermediate to high in SEE compared to other European countries, indicating potentially a higher risk of nitrogen effects on ecosystems than computed by the critical loads. Little data is available on nitrogen deposition and impacts on vegetation in South-East Asia.

3.3 Ozone

For the first time, the ICP Vegetation has mapped the risk of adverse impacts of ozone on vegetation for the extended EMEP domain using the flux-based metric POD_Y[2] (**Figure 3.3**). The concentration-

[2] Phytotoxic ozone dose above a flux threshold of Y nmol m^{-2} projected leaf area s^{-1}

based approach (AOT40[3]) identifies the southern part of the EECCA region at highest risk, whereas the biologically more relevant flux-based approach (POD_Y) identifies the south-western part of the region bordering with Central Europe at highest risk. Both approaches indicate that the northern part of the region is at lowest risk of adverse impacts from ozone pollution. Field-based evidence is available for ozone impacts on crops in Greece and Slovenia, with many crop species showing visible leaf injury in Greece (Hayes et al., 2007). Both AOT40 and POD_Y were computed to be high in SEE, indicating that this area is at high risk of ozone damage to vegetation.

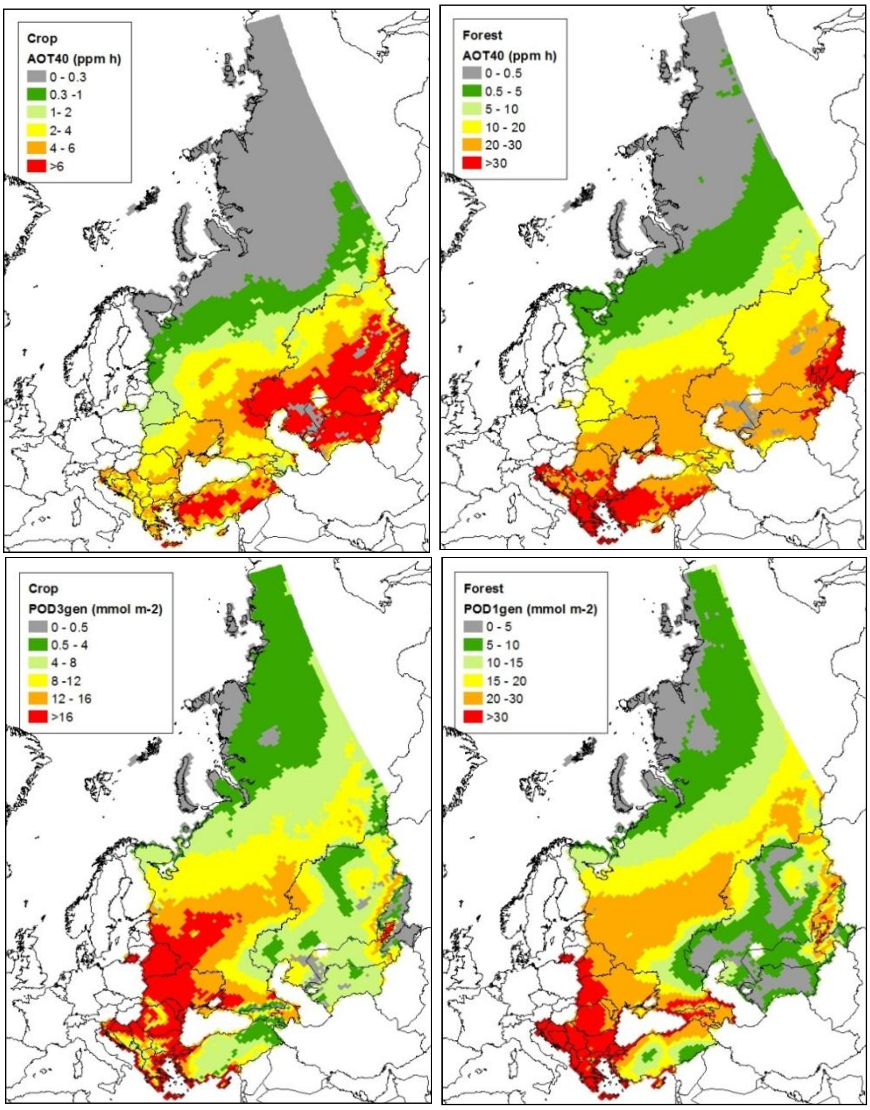

Figure 3.3 Indication of the spatial pattern of vegetation at risk of adverse impacts of ozone in EECCA and SEE countries, averaged over the period 2007-2011. Maps are shown for the concentration-based approach (AOT40; top) and the flux-based approach (POD_Y; bottom). The flux-based risk is shown for a generic crop species (left) and a generic tree species (right) as defined for integrated assessment modelling (LRTAP Convention, 2011). Data per 50 km x 50 km grid were downloaded from the EMEP/MSC-West web site.
Note: The flux model used to generate the data in this figure provides an estimation of the worst case for damage with adequate water supply (either rain-fed or irrigated). Reductions in ozone flux associated with dry soils such as those found in arid regions are not included in this model, for example in areas where crop irrigation is not used.

Staple food crops (maize, rice, soybean and wheat) are sensitive to moderately sensitive to ozone, threatening global food production. Recent flux-based risk assessment of ozone-induced wheat yield

[3] The accumulated hourly mean ozone concentration above 40 ppb, during daylight hours

loss show that the estimated relative yield loss was 6.4-14.9% for China and 8.2-22.3% for India in 2000, with higher yield losses predicted for 2020 (Tang et al. 2013), indicating the urgent need for curbing the rapid increase in surface ozone concentrations in this region. Worryingly, yield reductions of 20-35% have been recorded for various crop species when comparing yield in clean air with that in current ambient ozone concentrations in South-East Asia.

Asian crop yield and economic loss assessments made using North American or similar European based dose-response relationships may underestimate the damage caused by ozone (Emberson et al., 2009). As such, there is an urgent need for co-ordinated experimental field campaigns to assess the effects of ozone across South-East Asia (and the rest of Asia) to allow the development of dose-response relationships for Asian cultivars and growing conditions leading to improved quantification of current and future impacts of ozone on food production.

3.4 Heavy metals

Generally, deposition of heavy metals has declined in recent decades in EECCA and SEE countries, in agreement with the general decline computed for the rest of Europe, with the highest decline being reported for lead (Ilyin et al., 2013). However, apart from the western part of the EECCA region, the decline has generally been lower for EECCA and SEE countries compared to the rest of Europe. In 2011, the highest levels of metal deposition were computed in SEE countries, the south-western part and some (south-)eastern parts of the EECCA region. This might explain the relatively high concentrations of many heavy metals in mosses in countries in SEE Europe compared to the rest of Europe in recent years (Harmens et al., 2008, 2010, 2013c). High critical load exceedances have been reported for Macedonia for cadmium and lead and for Bosnia-Herzegovina and Russian Federation for lead (**Figure 3.4**; Slootweg et al., 2010). Widespread exceedance of the critical load for mercury has been observed in this region, similar to the rest of Europe. In India, the deposition of many heavy metals onto fruit and vegetables has been found to exceed WHO and Indian national limits for safe consumption.

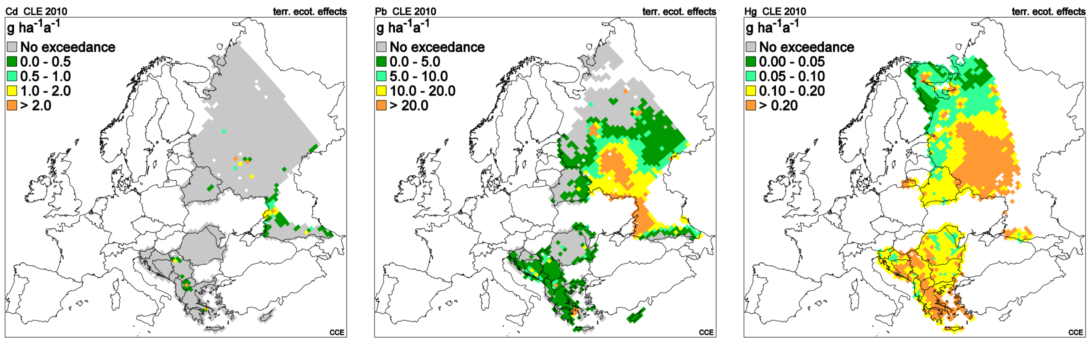

Figure 3.4 Average accumulated exceedance (AAE) of critical loads for cadmium (left), lead (middle) and mercury (right) for terrestrial ecological effects in 2010 in eastern and south-eastern Europe. Source: Coordination Centre for Effects.

3.5 Persistent organic pollutants (POPs)

Model assessment by EMEP/MSC-East indicate a reduction of POP pollution in most of the EECCA and SEE countries between 1990 to 2011, particularly for hexachlorobenzene (HCB), although generally lower than for the rest of Europe; highest reductions were observed in the western part of the region (Gusev et al., 2013). In 2011, the highest deposition for benzo[a]pyrene and polychlorinated dibenzodioxin were computed in the south-western part of the region, whereas HCB levels were high for large parts of the Russian Federation (**Figure 3.5**).

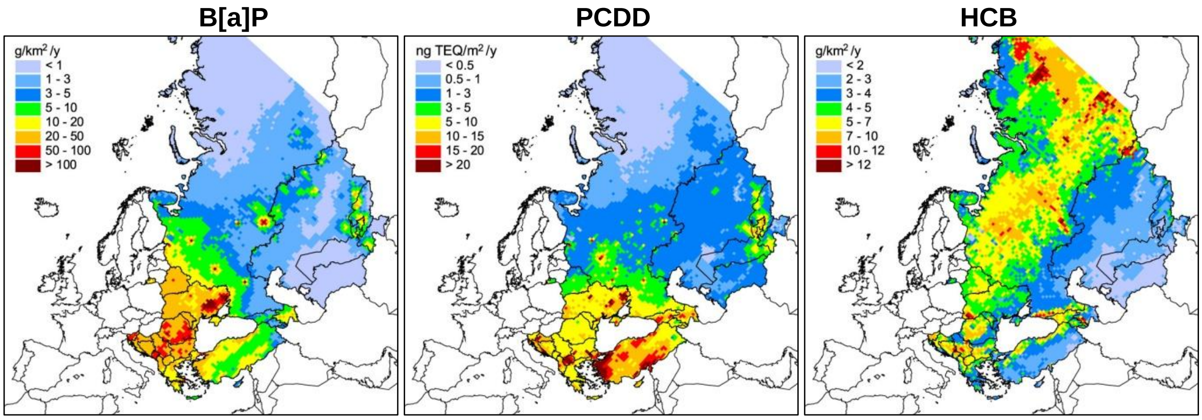

Figure 3.5 Deposition fields of B[a]P, PCDD and HCB in EECCA and SEE countries in 2011 Source: EMEP/MSC-East.

3.6 Aerosols

South Asia is a region with high aerosol load compared to other regions, due its rapid growth and the arid climate. In particular the Indo-Gangetic Plain, South Asia's most important agricultural region, persistently has very high aerosol load, reducing visibility as well as solar radiation reaching the surface. Reduced photosynthesis might occur as a result of reduced solar radiation and larger aerosols blocking leaf pores, although the increase in diffuse radiation might have the opposite effect on photosynthesis.

3.7 Conclusions and recommendations

There is a lack of monitoring data regarding the deposition to and impacts of air pollutants on vegetation in EECCA/SEE countries and South-East Asia. It would be desirable to further enlarge coordinated networks to measure air concentrations and depositions of air pollutants, i.e. to extend the EMEP monitoring network in the EECCA/SEE region and establish a similar network in South-East Asia, for example by extending the Acid Deposition Monitoring Network in East Asia (EANET) by including other regions and more pollutants. International Cooperative Programmes of the LRTAP Convention might consider further stimulating the development of coordinated networks in these regions with the aim to establish widespread monitoring networks assessing the impacts of air pollutants on ecosystems. More measurement data are urgently needed to validate model outputs regarding the concentrations, deposition and associated risk for impacts of air pollutants on vegetation. The successful implementation of air pollution abatement policies in many other parts of Europe has highlighted the slower progress made with some of the air pollution abatement in the Eastern Europe, the Caucasus, Central and South-East Asia. Improvement of air quality in these regions will also benefit the rest of Europe due to a reduction of long-range transport of air pollutants, particularly those of hemispheric importance such as ozone and mercury. Many air pollution issues are remaining in the studied areas that require urgent attention, especially in regions of fast economic and population growth, ensuring future sustainable development without significant impacts on the functionality of ecosystems, the services they provide and food production.

4 Recent developments of the flux-based approach for setting critical levels of ozone for vegetation

In this chapter we provide an overview of the decisions and recommendations from the Task Force at its 27th meeting in 2014, resulting in an update of Chapter 3 ('Mapping critical levels for vegetation') of the Modelling and Mapping Manual of the LRTAP Convention (LRTAP Convention, 2014).

4.1 Introduction

Earlier versions of the Modelling and Mapping Manual included concentration-based critical levels that used AOTX (ozone concentrations accumulated over a threshold of X ppb during daylight hours) as the ozone parameter. However, several important limitations and uncertainties have been recognised for using AOTX. In particular, the real impacts of ozone depend on the amount of ozone reaching the sites of damage within the leaf, whereas AOTX-based critical levels only consider the ozone concentration at the top of the canopy. The Gerzensee Workshop in 1999 recognised the importance of developing an alternative critical level approach based on the flux of ozone from the exterior of the leaf through the stomatal pores to the sites of damage (stomatal flux). This approach required the development of mathematical models to estimate stomatal flux, primarily from knowledge of stomatal responses to environmental factors (Emberson et al., 2000; http://sei-international.org/do3se). At the Gothenburg Workshop in 2002 it was agreed that ozone flux-effect models were sufficiently robust for the derivation of flux-based critical levels, and subsequently such critical levels were included in the manual. An additional simplified flux-based "worst-case" risk assessment method for use in large-scale and integrated assessment modelling was discussed at the Obergurgl Workshop (2005) and included in the Manual after further revision (approved at appropriate Task Force meetings) for a generic crop and forest trees species. Recently, a critical level has been derived for effects on a generic crop (see Section 4.2), but not for effects on trees. This simplified method does not take into account effects of soil moisture and thus provides a "worst-case" risk asssement. At the Ispra Workshop in 2009 and subsequent 23rd Task Force meeting of the ICP Vegetation in 2010, the flux-based critical levels were reviewed, revised where needed, and added for new receptors (Mills et al., 2011b). Chapter 3 of the Modelling and Mapping Manual was further updated in 2014 to include reference to publications of included functions, models etc., a revised method for use in Integrated Assessment Modelling and updated Annexes including flux models for additional species and updated models for some receptors as approved at the 27th Task Force meeting of the ICP Vegetation in 2014.

4.2 Estimation of risk of damage using a generic crop flux model (for integrated assessment modelling within GAINS)

The simplified flux model, response function and associated critical level described in this section **are for integrated assessment modelling** at the European scale. They are provided for use in scenario analysis and optimisation runs within the GAINS (**G**reenhouse Gas and **A**ir Pollution **In**teractions and **S**ynergies) model to provide an indication of potential effects on wheat yield under non-limiting water availability. The parameterisation for ozone exposure (stomatal flux), as calculated for the source-receptor matrix used in GAINS, should be based on two parameterisations for cereals: i) Northern and Central Europe; ii) Mediterranean areas. For local and national application, it is recommended that the full wheat flux model is used, including for Mediterranean areas, the Mediterranean-specific parameterisation (LRTAP Convention, 2014).

The generic crop flux method described here is intended to be used to provide estimates of the potential effective phytotoxic cumulative stomatal ozone uptake and hence should be viewed as an indicator of the degree of risk for crop loss with a stronger biological basis than AOT40. The flux model described here is a simplified model for application in large-scale modelling, including integrated assessment modelling (IAM) and uses a lower threshold (Y = 3 compared to Y = 6 nmol m^{-2} s^{-1} for the full flux model) and a longer time interval for accumulation of flux. It is suggested to use a time window of three months (90 days) symmetrically around the estimated date for anthesis (flowering) in wheat as identified by data collection within the ICP Vegetation.

The parameterisation for this generic flux model (LTRAP Convention, 2014) is based on the full flux model for wheat and includes a separate parameterisation for application in i) Northern and Central Europe and ii) Mediterranean areas, including both Eastern and Western Mediterranean areas (González-Fernández et al., 2013). As the modifying effect of soil moisture on stomatal conductance is not included in the simplified crop flux model then this method indicates the **risk of damage under a worst case scenario** where soil moisture is not limiting to flux. Thus even using the Mediterranean parameterisation, this approach may over-estimate risk of damage for non-irrigated crops in dry climates because of the lack of inclusion of a soil moisture parameterisation. Since several aspects of the parameterisation are changed compared to the full flux model for wheat, the exposure index used will be denoted POD_3IAM (formerly described as $POD_{3\ gen}$) to indicate that this flux model is for use in large scale integrated assessment modelling, and that this is a different parameter to POD_3 calculated using the full flux model.

The ICP Vegetation Task Force recommended **that any tables or maps produced using this generic crop approach should include the following text** within the legend:

> Note: The generic crop flux model used to generate the data in this table/map provides an estimation of the worst case for damage for crops with adequate water supply (either rain-fed or irrigated). Reductions in ozone flux associated with dry soils such as those found in Mediterranean areas are not included in this model and thus effects may be over-estimated where irrigation is not used in these areas.

The flux-effect relationship shown in **Figure 4.1** was derived from the experimental data used to establish the response function using the full flux model for wheat. It should be noted that the flux-effect relationship was first derived for datasets based on 45 days; the values have been doubled to accomodate the longer 90 day time interval required for GAINS. Some uncertainty arises from this approach, but the Task Force agreed that this was an acceptable level of uncertainty within large scale modelling.

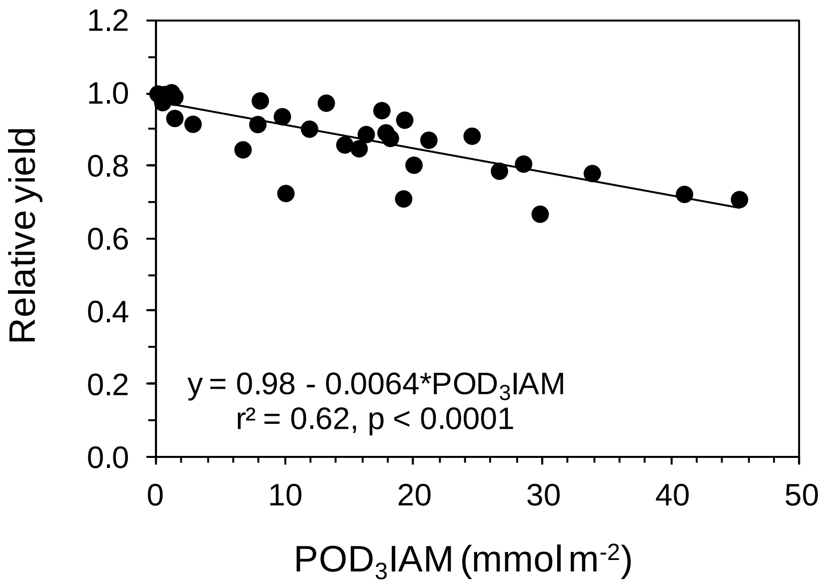

Figure 4.1 The relationship between relative yield and POD_3IAM (accumulated over 90 days) for a generic crop represented by wheat. Please see text for application of this relationship within GAINS.

Using the response function in Figure 4.1, a critical level representing a 5% reduction in crop yield has been derived for use in GAINS as a POD_3IAM of 8 mmol m^{-2} (accumulated over 90 days).

The ICP Vegetation Task Force endorsed all other critical levels as decribed in the previous version of the Modelling and Mapping Manual and recommended not to change them. Although the parameterisation for the stomatal flux model for tomato was recently updated (González-Fernández et al., 2014), indicating a change in the associated critical level, this information was not presented at the 27th Task Force meeting for adoption. However, it is anticipated that an update of the tomato parameterisation and associated critical level based on González-Fernández et al. (2014) will be approved for inclusion in the Modelling and Mapping Manual at the 28th Task Force meeting of the ICP Vegetation.

4.3 New parameterisations of the ozone stomatal flux model

Bread and Durum wheat grown in Mediterranean areas

New research has been published on the parameterisation of the ozone stomatal flux model for wheat growing in Mediterranean climates. González-Fernández et al. (2013) compiled data from 25 years of phenology data from areas representative of Mediterranean with Atlantic climate influence, coastal Mediterranean and continental Mediterranean climates together with stomatal conductance measurements made over five years for winter bread wheat (3 cultivars) and durum wheat (2 cultivars) growing near Madrid. The maximum stomatal conductance (g_{max}) was derived from a literature review of wheat growing under Mediterranean conditions. Details of the parameterisation for bread wheat and durum wheat for application in Mediterranean areas were described in González-Fernández et al. (2013) and have been included in the revised version of the Modelling and Mapping Manual (LRTAP Convention, 2014).

Regional application for grapevine, maize, soybean, sunflower and poplar

Based on newly available data, the 27th Task Force meeting agreed to the inclusion of new flux parameterisations for grapevine, maize, soybean, sunflower and poplar in the revised version of the Modelling and Mapping Manual (LRTAP Convention, 2014). Values for g_{max} were extracted from peer-reviewed literature. Only those studies were included that clearly stated the type of instrument used, the gas for which stomatal conductance was measured (water vapour, carbon dioxide or ozone), the reference area (projected or measured), the name of the cultivar (European were preferred over North American cultivars; no tropical cultivars were used), the age of the plant or leaf used for stomatal conductance measurements, the timing of the measurements and the climatic conditions during the measuring campaign (field experiments were preferred over glasshouse or chamber experiments). Data points referring to the total leaf area were recalculated to represent the projected leaf area as reference. If g_{max} was reported for water vapour (g_{max} mmol H_2O m^{-2} PLA s^{-1}), which was the case in the majority of papers, it was converted to g_{max} for O_3 (g_{max} mmol O_3 m^{-2} PLA s^{-1}) using the conversion factor of 0.663 (Grünhage et al., 2012) to account for the difference in the molecular diffusivity of water vapour to that of ozone. Values for g_{max} are provided in **Table 4.1**.

Table 4.1 The maximum stomatal conductance (g_{max}) for four crop species and one tree species.

	Grapevine (*Vitis vinifera*)	Maize (*Zea mays*)	Soybean (*Glycine max*)	Sunflower (*Helianthus annuus*)	Poplar (*Populus sp*)
Median g_{max} (mmol O_3 m^{-2} PLA s^{-1})	229	326	706	386	392
standard deviation (mmol O_3 m^{-2} PLA s^{-1})	72	28	291	139	177
No. of studies	14	6	8	13	7
No. of data points	23	6	8	15	10

In addition, parameterisations of the ozone flux model for local-scale risk assessment in the Mediterranean area have been published for tomata (González-Fernández et al., 2014), bean (Gerosa et al., 2009) and barley (Gerosa et al., 2004). However, they have not currently been approved by the ICP Vegatation Task Force for use on a European scale.

4.4 Further development of ozone risk assessment methodologies

The ICP Vegetation Task Force made recommendations at its 27th meeting to further develop ozone risk assessment methodologies, as described below. The developments will be reviewed at the 28th ICP Vegetation Task Force meeting in 2015:

General recommendations

- Further epidemiological studies should be conducted to validate critical levels. The methodology to separate climate and direct ozone effects should be discussed amongst experts. Recently, Switzerland has organised a one-day workshop (16 – 17 September, 2014, Basel) on this topic as a contribution in kind;
- Further development of process-based flux models (e.g. based on Ball-Berry model) is encouraged;
- The simplified flux methodology as developed for national application in Sweden should also be tested for other climates;
- Develop a multi-layer, multi-species version of the DO_3SE (**D**eposition of **O**zone for **S**tomatal **E**xchange) model for up-scaling to canopy level;
- Further develop the non-stomatal deposition term in the DO_3SE model;
- Further develop flux-based critical levels for visible ozone injury, including the use of data from tree surveys in Italy and France;
- Develop dose-response relationships for plant functional types;
- Develop flux-effect relationships and associated critical levels for vegetation, taking into account modifying factors such as other pollutants (specifically nitrogen) and climate change;

Recommendations for crops

- Revision of the tomato flux-effect relationship and the associated critical level, based on the availability of new data (González-Fernández et al., 2014);
- Expansion of range of species with flux-effect relationships.

Recommendations for trees

- Revision of forest tree flux-effect relationships based on updated analyses;
- Develop flux-based critical levels for different endpoints, e.g. net annual increment of tree biomass and flux-effect relationships based on leaf mass area.

Semi-natural vegetation

- A list of species for which flux-effect relationships are available should be made available on the ICP Vegetation web site;
- Potential for grouping of species using different approaches for dividing them into ecologically relevant groups (e.g. annuals, perennials, legumes).

5 Common WGE and other ICP Vegetation activities in 2013/2014

In this chapter, progress made with the common WGE and other ICP Vegetation workplan items for 2014 is summarised.

5.1 Contributions to WGE common workplan items

5.1.1 Further implementation of the Guidelines on Reporting of Air Pollution Effects

Table 5.1 provides an overview of the monitoring and modelling effects reported by the ICP Vegetation according to the Guidelines (ECE/EB.AIR/2008/11).

Table 5.1 Monitoring and modelling effects reported by the ICP Vegetation.

Parameter	Ozone	Heavy metals	Nitrogen	POPs
Growth and yield reduction	X			
Leaf and foliar damage	X			
Exceedance critical levels	X			
Climatic factors	X			
Concentrations in mosses		X	X	X

5.1.2 Enhanced involvement of countries in Eastern and South-Eastern Europe, the Caucasus and Central Asia, and cooperation with activities outside the Convention

In 2014, ICP Vegetation transferred the coordination of the European moss survey (i.e., monitoring heavy metals, nitrogen and persistent organic pollutant (POP) concentrations in mosses every five years) to the Russian Federation. The new Moss Survey Coordination Centre, at the Institute for Joint Nuclear Research in Dubna, is negotiating for or has reached agreement on the participation of countries in Eastern Europe, the Caucasus and Central Asia (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, the Republic of Moldova, the Russian Federation and Uzbekistan) and selected other Asian countries (China, India, Mongolia, Pakistan, Republic of Korea, Thailand and Viet Nam) for the next survey in 2015/16. The updated Moss Monitoring Manual (ICP Vegetation, 2014) for the 2015/16 moss survey was translated into Russian. In addition, a glossy leaflet on ozone injury symptoms on leaves of vegetation was also translated into Russian.

ICP Vegetation published the report on ‘Air pollution: Deposition to and impacts on vegetation in (South-) East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia; a country report was included for the Russian Federation and various countries in South-Eastern Europe (Albania, Croatia, Greece, Romania, Serbia, Slovenia and the former Yugoslav Republic of Macedonia). This report was translated into Russian (for further details see Chapter 3 or Harmens and Mills, 2014).

5.1.3 Cooperation with programmes and activities outside the region

ICP Vegetation co-organised the ‘Ozone and Plants’ Conference in Beijing, China, May 2014, in collaboration with the Chinese Academy of Sciences and the International Union of Forest Research Organizations (IUFRO). ICP Vegetation is keen to continue its collaboration with the Chinese Academy of Sciences and IUFRO in the future and stimulate further outreach activities outside the ECE region.

5.2 Supporting evidence for ozone impacts on vegetation

5.2.1 Ozone biomonitoring using bean

Since 2008, participants of the ICP Vegetation have been conducting biomonitoring campaigns using ozone-sensitive (S156) and ozone-resistant (R123) genotypes of *Phaseolus vulgaris* (Bush bean, French Dwarf bean) that had been selected at the USDA-ARS Plant Science Unit field site near Raleigh, North Carolina, USA (Reinert and Eason, 2000; Burkey et al., 2005). Seeds of ozone sensitive (S-156) and ozone resistant (R-123) *Phaseolus vulgaris* (bean) were kindly provided by Kent Burkey of the USDA-ARA Plant Research Unit, Raleigh, USA. In 2012, the biomonitoring of ozone effects using bean was scaled down compared to the previous years, reflecting less interest from the participants. In 2013, seeds and a standard protocol were sent out to participants from Algeria, China (3 sites), Croatia, Italy, Niger, Pakistan, Poland and Ukraine. Many of these countries were participating in the ozone biomonitoring studies for the first time. Due to the differences in growing season, analysis of data are ongoing in Niger and Algeria. Visible leaf injury attributed to ozone was observed in China, Italy, Pakistan and Poland. In China, visible leaf injury was also apparent on local bean cultivars growing in/near Beijing (**Figure 5.1**). Ozone concentrations were higher in the suburbs of Beijing than in central Beijing. In central Beijing and the suburbs there was a large reduction (>50%) in pod number and seed yield of the sensitive compared to the resistant variety, but there was a smaller reduction at the site in a more rural region with much lower ozone concentrations.

a) b)

Figure 5.1 a) Reduction in growth of the ozone-sensitive (on the left) compared to ozone-resistant (on the right) varieties of bean in central Beijing, and b) ozone leaf injury on local bean cultivars.

5.2.2 Smart-phone application for recording incidences of ozone-induced leaf injury

In 2007, the ICP Vegetation published a synthesis report documenting over 600 incidences of ozone injury on crops, grassland species and shrubs growing in the field under ambient air conditions in 16 countries of Europe (Hayes et al., 2007; Mills et al., 2011a). We aim to revisit this study in the future by compiling new spatial data on current incidences of ozone injury. Using smart-phone technology for i-phones and android phones, and a web-based recording methodology, we have developed a new way of recording incidences of ozone injury in the field.

The smart phone App (**Figure 5.2**) allows participants to upload photographs of ozone injury direct from the field together with the coordinates for the location where the injury was detected. App users are taken through a short series of questions, with answers selected from drop-down menus. The broad vegetation types of the damaged species (from Crop, Tree, Grassland, Heathland, Wetland and Coastal) and the species name can be chosen from a list. The species list is based on species with observed ozone injury symptoms recorded in the field (Hayes et al., 2007; Mills et al., 2011a), whilst ensuring those chosen are also widespread and easy to identify. Information on the symptoms of ozone injury (including the colour, location on the leaf and age of damaged leaves) is also requested from the user.

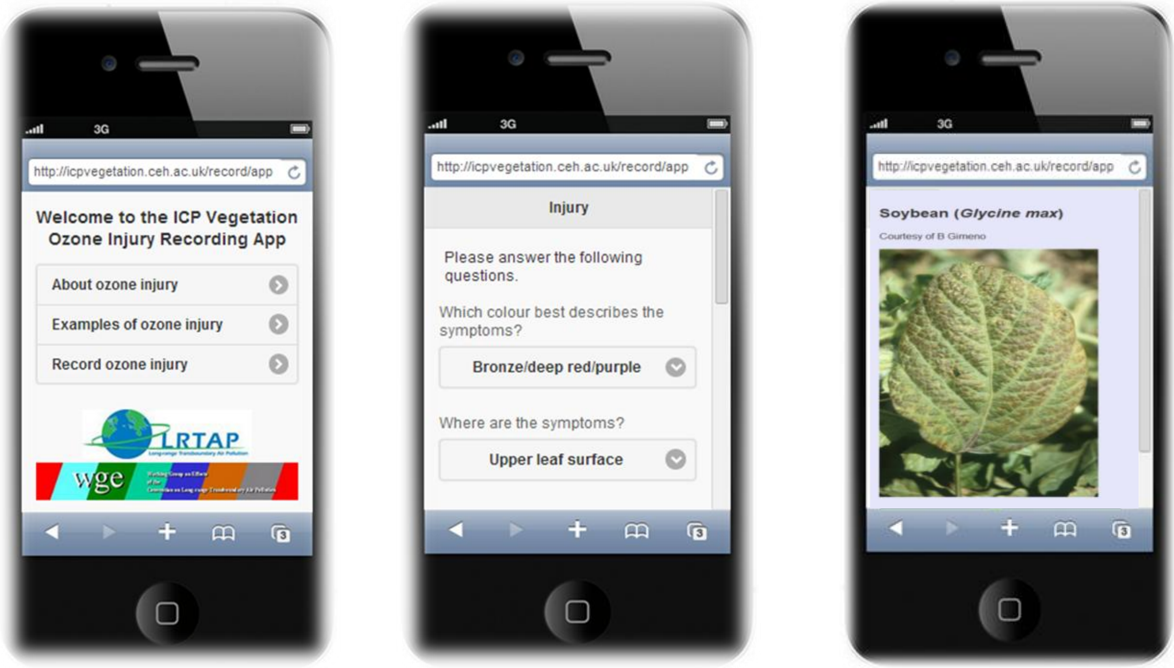

Figure 5.2 Smart phone App for recording incidences of ozone-induced leaf injury.

Questions designed to assist with quality assurance, for example, specifying any previous experience of identifying ozone damage or plant diseases and describing recent weather conditions are also being asked. Additionally, the App contains an 'Ozone information' section, which includes details of the key symptoms of ozone injury, and other causes of leaf damage that may be mistakenly recorded as ozone injury. There is an 'Examples of ozone injury' page, containing photos of ozone injury on many of the species included in the App species list. The App is tested in 2014 by ozone experts and is scheduled for release to a wider audience in 2015. Further details are available at http://icpvegetation.ceh.ac.uk/record/index.

Recently we have also produced a brochure on ozone and ozone injury for farmers, land managers, non-specialist scientists and policy makers (**Figure 5.3**). This provides detailed information and photographs of the symptoms of ozone injury on a variety of vegetation types, and encourages the use of the new App (if these symptoms are observed). This leaflet was also translated into Russian as a contribution in kind from the ICP Vegetation participant of the Russian Federation. The leaflet was produced in close collaboration with the Expert Panel of Ambient Air Quality of the ICP Forests.

Figure 5.3. Brochure on ozone-induced leaf injury.

5.2.3 Progress in preparations for the European moss survey 2015/16 on heavy metals, nitrogen and persistent organic pollutants

Coordination of the 2015/16 European moss survey was successfully transferred to the new Moss Survey Coordination Centre in the Russian Federation (http://flnp.jinr.ru/naa). The moss monitoring manual (ICP Vegetation, 2014) was updated in collaboration with potential participants and was translated into Russian to stimulate participation from EECCA countries. We encourage Parties of the LRTAP Convention to provide funding for participation of as many countries as possible in the survey.

6 Medium-term workplan (2015-2017)

The medium-term workplan for 2015 – 2017 was adopted at the 27th Task Force Meeting of the ICP Vegetation (Paris, France, 28 - 30 January, 2014). Workplan items for 2015 were already approved at the 32nd session of the Executive Body of the LRTAP Convention in December 2013 (see ECE/EB.AIR/122/Add.2). Workplan items for 2016 and 2017 have been proposed by the Task Force.

Ongoing annual activities:

- Report on supporting evidence for ozone impacts on vegetation;
  (*Note: this includes bean biomonitoring and smart phone App for recording incidences of ozone injury*)
- Report on preparations and progress with the moss survey 2015/2016;
- Contributions to common workplan items of the WGE (see Section 5.1 for details).

New activities:

2015:

- Report on the implications of rising background ozone for vegetation in Europe;
- Report on the interacting effects of co-occurring pollutants (ozone and nitrogen) and climatic stresses on vegetation.

Tentatively for 2016:

- Update report on field-based evidence of ozone impacts on vegetation;
- Report on ozone impacts on biodiversity;
- Ozone critical levels workshop.

Tentatively for 2017:

- Report on revised ozone risk assessments methods;
- Revision of Chapter 3 of the Modelling and Mapping Manual;
- Report of the European moss survey 2015/16.

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Annex 1. Participation in the ICP Vegetation

In many countries, several other scientists (too numerous to include here) also contribute to the work programme of the ICP Vegetation. P in heavy metals column indicates involvement in POPs research.

Name/Country	Institute	Email	Ozone	Heavy metals	Nitrogen
Albania					
Pranvera Lazo	University of Tirana Faculty of Natural Sciences Tirana	pranveralazo@gmail.com		✓	
Flora Qarri	University of Vlora, Department of Chemistry, Vlora	flora.qarri@gmail.com		✓	
Austria					
Gerhard Soja	AIT Austrian Institute of Technology GmbH Konrad Lorenz-Str. 24 3430 Tulln	gerhard.soja@ait.ac.at	✓		
Harald Zechmeister	Dept. of Conservation Biology, Vegetation- and Landscape Ecology, University of Vienna Rennweg 14, 1030 Vienna	Harald.Zechmeister@univie.ac.at		✓	✓
Belarus					
Yulia Aleksiayenak	International Sakharov Environmental University, Minsk	beataa@gmail.com		✓	
Belgium					
Ludwig De Temmerman Karine Vandermeiren Nadia Waegeneers Ann Ruttens	Veterinary and Agrochemical Research Centre CODA-CERVA Leuvensesteenweg 17 B-3080 Tervuren	ludwig.detemmerman@coda-cerva.be karine.vandermeiren@coda-cerva.be nadia.waegeneers@coda-cerva.be ann.ruttens@coda-cerva.be	✓	✓	✓
Bulgaria					
Lilyana Yurukova	IBER - Base 3 - ex-Institute of Botany,Bulgarian Academy of Sciences, Acad. G.Bonchev Str., Block 23, 1113 , Sofia	(passed away in August 2014)		✓	✓
Savka Miranova	Department of Atomic Physics Plovdiv University Paisii Hilendarski Tsar Assen Str. 24 4000 Plovdiv	savmar@pu.acad.bg		✓	
Croatia					
Zdravko Spiric	Oikon Ltd. Institute for Applied Ecology Trg senjskih uskoka 1-2 10020 Zagreb	zspiric@oikon.hr	✓	✓	✓
Czech Republic					
Ivan Suchara Julie Sucharová	Silva Tarouca Research Institute for Landscape and Ornamental Gardening Kvetnove namesti 391 CZ-252 43 Pruhonice	suchara@vukoz.cz sucharova@vukoz.cz		✓	✓
Denmark (Faroe Islands)					
Maria Dam Katrin Hoydal	Environment Agency Traðagøta 38 FO-165 Argir	mariad@us.fo katrinh@us.fo		✓	
Estonia					
Siiri Liiv	Tallinn Botanic Garden Kloostrimetsa tee 52 11913 Tallinn	siiri.liiv@botaanikaaed.ee		✓	✓

Name/Country	Institute	Email	Ozone	Heavy metals	Nitrogen
Finland					
Eero Kubin Juha Piispanen Jarmo Poikolainen Jouni Karhu	Finnish Forest Research Institute Oulu, PO Box 413, 90014 University of Oulu	Eero.Kubin@metla.fi Juha.Piispanen@metla.fi Jarmo.Poikolainen@metla.fi Jouni.Karhu@metla.fi		✓	✓
Sirkku Manninen	Department of Environmental Sciences, P.O. Box 56 00014 University of Helsinki	sirkku.manninen@helsinki.fi	✓		
Former Yugoslav Republic of Macedonia					
Trajce Stafilov Lambe Barandovski	Institute of Chemistry, Faculty of Science, SS. Cyril and Methodius University Arhimedova 5, Skopje	trajcest@pmf.ukim.mk lambe@pmf.ukim.mk		✓	
France					
Jean-François Castell Olivier Bethenod	UMR EGC/AgroParisTech-INRA 78850 Thiverval-Grignon	castell@grignon.inra.fr bethenod@grignon.inra.fr	✓		
Laurence Galsomiès	ADEME, Deptartment Air 27 rue Louis Vicat 75737 Paris Cedex 15	laurence.galsomies@ademe.fr		✓	✓
Jean-Paul Garrec Didier le Thiec	INRA-Nancy F-54280 Champenoux	garrec@nancy.inra.fr lethiec@nancy.inra.fr	✓		
Sebastien Leblond	Muséum National d'Histoire Naturelle France, CP 39 57 rue Cuvier, 75005 Paris	sleblond@mnhn.fr		✓ P	✓
Pierre Louis Sicard	ACRI-ST, 260 route du Pin Montard, BP 234 06904 Sophia-Antipolis Cedex	pierre.sicard@acri-st.fr	✓		
Matthieu Baggard Anne Repellin	Université Paris Est Créteil	matthieu.bagard@u-pec.fr repellin@u-pec.fr	✓		
Valérie Simon	Institut National Polytechnique de Toulouse 4 Allée Emile Monso 31432 Toulouse Cedex 4	Valerie.Simon@ensiacet.fr	POPs		
Germany					
Jürgen Bender	Institute of Biodiversity Johann Heinrich von Thünen-Institute (vTI), Bundesallee 50 D-38116 Braunschweig	juergen.bender@vti.bund.de	✓		
Ludger Grünhage	Institute for Plant Ecology Justus-Liebig-University, Heinrich-Buff-Ring 26-32 D-35392 Giessen	Ludger.Gruenhage@bot2.bio.uni-giessen.de	✓		
Winfried Schröder Michaela Meyer (formerly: Kluge) Stefan Nickel	Hochschule Vechta, Institute für Umweltwissenschaften Postfach 1553 D-49364 Vechta	wschroeder@iuw.uni-vechta.de michaela.meyer@uni-vechta.de stefan.nickel@uni-vechta.de		✓	✓
Willy Werner Stephanie Boltersdorf	University Trier, Department of Geobotany, Behringstr. 5 54286 Trier	werner@uni-trier.de Stefanie.Boltersdorf@gmx.de	✓		✓
Greece					
Dimitris Velissariou	Technological Educational Institute of Kalamata Antikalamos 241 00, Kalamata	d.velissariou@teikal.gr	✓		
Costas Saitanis	Agricultural University of Athens Laboratory of Ecology & Environmental Sciences Iera Odos 75 Botanikos 11855, Athens	saitanis@aua.gr	✓		
Iceland					
Sigurður Magnússon	Icelandic Institute of Natural History, Hlemmur 3, 125 Reykjavík	sigurdur@ni.is		✓	

Name/Country	Institute	Email	Ozone	Heavy metals	Nitrogen
Italy					
Stanislaw Cieslik Ivano Fumagalli	European Commission, Joint Research Centre - Institute for Environment and Sustainability Via E. Fermi, 2749, I-21027 Ispra (VA)	stanislaw.cieslik@yahoo.it ivan.fumagalli@jrc.it	✓		
Gianfranco Rana Marcello Mastrorilli	CRA-Research Unit for Agriculture in Dry Environments via C. Ulpiani, 5 70125 Bari	gianfranco.rana@entecra.it marcello.mastrorilli@entecra.it	✓		
Fausto Manes Marcello Vitale Elisabetta Salvatori Lina Fusaro	Dipartimento di Biologia Vegetale, Università di Roma "La Sapienza", Piazzale Aldo Moro 5, 00185 Rome	fausto.manes@uniroma1.it marcello.vitale@uniromal.it elisabetta.salvatori@uniroma1.it lina.fusaro@uniroma1.it	✓		
Renate Alber	Environmental Agency of Bolzano, Biological Laboratory Via Sottomonte 2 I-39055 Laives	Renate.Alber@provinz.bz.it		✓	✓
Alessandra de Marco	ENEA, CR Casaccia Via Anguillarese 301 00060 S. Maria di Galeria, Rome	alessandra.demarco@enea.it	✓		
Giacomo Gerosa Angelo Finco Riccardo Marzuoli	Universita' Cattolica del S.c. di Brescia, Via Pertini 11 24035 Curno	giacomo.gerosa@unicatt.it angelo.finco@unicatt.it riccardo.marzuoli@unicatt.it	✓		
Silvano Fares	Agricultural Research Council Research Centre for the Soil-Plant System Via della Navicella 2-4 00184 Rome, Italy	silvano.fares@entecra.it	✓		
Elena Paoletti	Istituto Protezione Piante Cons. Nazionale delle Ricerche Via Madonna del Piano 10 50019 Sesto Fiorentino (Firenze)	e.paoletti@ipp.cnr.it	✓		
Cristina Nali Lorenzo Cotrozzi	University of Pisa Via del Borghetto 80 56124 Pisa	cristina.nali@unipi.it lorenzo.cotrozzi@for.unipi.it	✓		
Kosovo (United Nations administered territory, Security Council resolution 1244 (1999))					
Albert Maxhuni	University of Pristina	contact: pranveralazo@gmail.com		✓	
Latvia					
Marina Frolova	Latvian Environment, Geology and Meteorology Agency Maskavas Str. 165 Riga, LV 1019	marina.frolova@lvgma.gov.lv		✓	✓
Inara Melece	University of Latvia	inaramelece@inbox.lv	✓		
Lithuania					
Kestutis Kvietkus	Institute of Physics Savanoriu Ave 231 LT-02300 Vilnius	kvietkus@ktl.mii.lt		✓	
Netherlands					
Martijn Schaap	TNO, Dept. of Climate, Air and Sustainability P.O.Box 80015 3508 TA Utrecht	martijn.schaap@tno.nl		✓	✓
Norway					
Eiliv Steinnes Torunn Berg	Norwegian University of Science and Technology NO-7491 Trondheim	eiliv.steinnes@chem.ntnu.no torunn.berg@chem.ntnu.no		✓ P	
Hilde Uggerud Martin Schlabach	Norwegian Institute for Air Research (NILU), 2027 Kjeller	hilde.thelle.uggerud@nilu.no martin.schlabach@nilu.no		✓ P	
Poland					
Barbara Godzik, Grażyna Szarek-Łukaszewska, Pawel Kapusta	W. Szafer Institute of Botany Polish Academy of Sciences Lubicz Str. 46, 31-512 Krakow	b.godzik@botany.pl p.kapusta@botany.pl	✓	✓ P	✓

Name/Country	Institute	Email	Ozone	Heavy metals	Nitrogen
Klaudine Borowiak Justyna Urbaniak	August Cieszkowski Agricultural University of Poznan, ul. Piatkowska 94C, 61-691 Poznan	klaudine@up.poznan.pl justurb@up.poznan.pl	✓		
Romania					
Ion V. Popescu Claudia Stihi	Valahia University of Targoviste Faculty of Sciences and Arts, 2 Carol I street 130024 Targoviste	lucaciuadriana@yahoo.com stihi@valahia.ro		✓	
Simona-Maria Cucu-Man	Alexandru Ioan Cuza University of Iasi	sman@uaic.ro		✓	
Antoaneta Ene	Dunarea de Jos University of Galati	aene@ugal.ro		✓	
Radu Todoran	Tech. University of Cluj-Napoca North Center, Baia Mare	Todoran_radu@yahoo.com		✓	
Otilia Ana Culicov	National Institute for R&D in Electrical Engineering ICPE-CA Bucharest	culicov@nf.jinr.ru		✓	
Russian Federation					
Marina Frontasyeva (Head Moss Survey Coordination Centre) Konstantin Vergel Anatoly M. Dunaev Nina A. Lebedeva Inna V. Vikhrova	Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Joliot Curie 6 141980 Dubna Chemical Technological University of Ivanovo Liceum # 1, Volgorechensk, Kostromskaya Municipal Educational Centre, Tikhvin, Leningradskaya	marina@nf.jinr.ru verkn@mail.ru kannikkiy@inbox.ru ninal1964@mail.ru vix-inna@yandex.ru		✓	
Natalia Goltsova	Biological Research Institute St.Petersburg State University St Peterhof 198504 St. Petersburg	Natalia.Goltsova@pobox.spbu.ru		✓	
Yuliya Koroleva	Immanuel Kant Baltic Federal University, Kaliningrad	yu.koroleff@yandex.ru		✓	
Serbia					
Miodrag Krmar Dragan Radnovich	Faculty of Science University Novi Sad Trg Dositeja Obradovica 4 21000 Novi Sad	miodrag.krmar@dbe.uns.ac.rs dragan.radnovic@dbe.uns.ac.rs		✓	
Slovakia					
Blanka Maňkovská	Institute of Landscape Ecology Slovak Academy of Science, Štefánikova str. 3, 814 99 Bratislava, Slovakia	bmankov@stonline.sk		✓	✓
Slovenia					
Franc Batic Boris Turk Klemen Eler	University of Ljubljana, Biotechnical Faculty, Agronomy Department, Jamnikarjeva 101, 1000 Ljubljana	franc.batic@bf.uni-lj.si boris.turk@bf.uni-lj.si klemen.eler@bf.uni-lj.si	✓		
Zvonka Jeran	Jožef Stefan Institute Dep. of Environmental Sciences, Jamova 39, 1000 Ljubljana	zvonka.jeran@ijs.si		✓ P	✓
Mitja Skudnik	Slovenian Forestry Institute Vecna pot 2, 1000 Ljubljana	mitja.skudnik@gozdis.si		✓	✓
Spain					
J. Angel Fernández Escribano Alejo Carballeira Ocaña J.R. Aboal	Ecologia Facultad De Biologia Univ. Santiago de Compostela 15782 Santiago de Compostela	bfjafe@usc.es bfalejo@usc.es bfjaboal@usc.es		✓	✓
Vicent Calatayud	Fundacion CEAM, Parque Tech. C/Charles R Darwin 14 Paterna, E-46980 Valencia	vicent@ceam.es	✓		

Name/Country	**Institute**	**Email**	Ozone	Heavy metals	Nitrogen
Victoria Bermejo, Rocio Alonso, Ignacio González Fernández, Héctor Calvete Sogo	Departamento de Impacto Ambiental de la Energía CIEMAT, Ed 70 Avda. Complutense 22 28040 Madrid	victoria.bermejo@ciemat.es rocio.alonso@ciemat.es ignacio.gonzalez@ciemat.es hector.calvete@ciemat.es	✓		✓
Jesús Santamaria Sheila Izquieta	Universidad de Navarra Facultad de Ciencias Irunlarrea No 1 31008 Pamplona I, Navarra	chusmi@unav.es sizquieta@alumni.unav.es	✓	✓ P	✓
Javier Martínez Abaigar Encarnación Núñez Olivera Rafael Tomás Las Heras	CCT, Madre de Dios 51 Universidad de La Rioja 26006 Logroño, La Rioja	javier.martinez@unirioja.es		✓	✓
J. María Infante Olarte	Gobierno de La Rioja Dirección General de Calidad Ambiental y Agua Prado Viejo, 62 bis 26071 Logroño, La Rioja	dg.calidadambiental@larioja.org		✓	✓
Sweden					
Per-Erik Karlsson Gunilla Pihl Karlsson Helena Danielsson	IVL Swedish Environmental Research Institute PO Box 5302, SE-400 14 Göteborg	pererik.karlsson@ivl.se gunilla.pihl.karlsson@ivl.se helena.danielsson@ivl.se	✓	✓	
Håkan Pleijel	Environmental Science and Conservation, Göteborg University PO Box 464, S-40530 Göteborg	hakan.pleijel@dpes.gu.se	✓		
Switzerland					
Jürg Fuhrer Seraina Bassin Matthias Volk	Agroscope Research Station ART, Reckenholzstr. 191 CH-8046 Zurich	juerg.fuhrer@art.admin.ch seraina.bassin@art.admin.ch matthias.volk@art.admin.ch	✓		✓
Sabine Braun	Institute for Applied Plant Biology Sangrubenstrasse 25 CH-4124 Schönenbuch	sabine.braun@iap.ch	✓		
Lotti Thöni	FUB-Research Group for Environmental Monitoring Alte Jonastrasse 83 CH-8640 Rapperswil-Jona	lotti.thoeni@fub-ag.ch		✓ P	✓
Marcus Schaub	Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürcherstrasse 111, 8903 Birmensdorf	marcus.schaub@wsl.ch	✓		
Turkey					
Mahmut Coskun	Canakkale Onsekiz Mart University, Health Service Vocational College 17100 Çanakkale	coskunafm@yahoo.com		✓	✓
Ukraine					
Oleg Blum	National Botanical Garden Academy of Science of Ukraine Timiryazevska St. 1, 01014 Kyiv	blum@nbg.kiev.ua	✓	✓	
United Kingdom					
Harry Harmens (Chairman), **Gina Mills** (Head of Programme Centre), Felicity Hayes, Katrina Sharps, Laurence Jones, David Norris, Jane Hall, David Cooper	Centre for Ecology and Hydrology Environment Centre Wales Deiniol Road Bangor Gwynedd LL57 2UW	hh@ceh.ac.uk, gmi@ceh.ac.uk fhay@ceh.ac.uk, katshar@ceh.ac.uk lj@ceh.ac.uk, danor@ceh.ac.uk jrha@ceh.ac.uk cooper@ceh.ac.uk	✓	✓	✓
Lisa Emberson Patrick Büker Alan Briolat Steve Cinderby	Stockholm Environment Institute, Biology Department University of York Heslington, York YO10 5DD	l.emberson@york.ac.uk patrick.bueker@york.ac.uk alan.briolat@sei-international.org sc9@york.ac.uk	✓		

Name/Country	Institute	Email	Ozone	Heavy metals	Nitrogen
Howard Cambridge		hmc4@york.ac.uk			
Bill Davies	Lancaster Environment Centre Lancaster University Lancaster LA1 4YQ	w.davies@lancaster.ac.uk	✓		
USA					
Kent Burkey	US Department of Agriculture ARS, N.C. State University 3908 Inwood Road Raleigh, North Carolina 27603	Kent.Burkey@ars.usda.gov	✓		
Outside UNECE region:					
Algeria					
Nadia Bouchenafa Abdelkader Dellal	Université Ibn Khaldoun Tiaret	nadiadellal@yahoo.fr dellal05_aek@yahoo.fr		✓	
China					
Zhaozhong Feng	Research Center for Eco-Environmental Sciences (RCEES), Chinese Academy of Sciences, 18 Shuangqing Road Haidian District, Beijing 100085	zhzhfeng201@hotmail.com	✓		
Cuba					
Jesús Ramirez	Institute of Meteorology, Cuba	jramirez_cu@yahoo.com	✓		
Egypt					
Samia Madkour	University of Alexandria, Damanhour	samiamadkour@yahoo.co.uk	✓		
India					
Dinesh Saxena	Department of Botany Bareilly College, Bareilly	dinesh.botany@gmail.com		✓	
Japan					
Yoshihisa Kohno	Central Research Institute of Electric Power Industry (CRIEPI	kohno@criepi.denken.or.jp	✓		
Niger					
Harouna Issa Amadou	Genetics & Plant Breeding Department of Biology University Abdou Moumouni Niamey	harounaiss@yahoo.com	✓		
Pakistan					
Sheikh Saeed Ahmad	Environ. Sciences Department Fatima Jinnah Women University The Mall, Rawalpindi	drsaeed@fjwu.edu.pk	✓		
Muhammad Andrees	Government College University Faisalabad	madrees@gcuf.edu.pk	✓		
South Africa					
Gert Krüger Jacques Berner	School of Environmental Sciences, North-West University, Potchefstroom, 2520	Gert.Kruger@nwu.ac.za jacques.berner@nwu.ac.za	✓		

Air Pollution and Vegetation
ICP Vegetation
Annual Report 2013/2014

This report describes the recent work of the International Cooperative Programme on effects of air pollution on natural vegetation and crops (ICP Vegetation), a research programme conducted more than 40 countries, in the UNECE region and with outreach activities to other regions. Reporting to the Working Group on Effects of the Convention on Long-range Transboundary Air Pollution, the ICP Vegetation is providing information for the review and revision of international protocols to reduce air pollution problems caused by ground-level ozone, heavy metals, nitrogen and persistent organic pollutants (POPs). Progress and recent results from the following activities are reported:

- Recent developments of the flux-based approach for setting critical levels of ozone for vegetation.
- Development of a smart-phone application to record incidences of ozone-induced leaf injury on vegetation.
- Air pollution deposition to and impacts on vegetation in (South-)East Europe, Caucasus, Central Asia (EECCA/SEE) and South-East Asia.
- Preparations for European heavy metals and nitrogen in mosses survey 2015/2016.

For further information please contact:

Harry Harmens
Centre for Ecology and Hydrology
Environment Centre Wales
Deiniol Road
Bangor
Gwynedd LL57 2UW
United Kingdom
Tel: +44 (0) 1248 374500
Fax: +44 (0) 1248 362133
Email: hh@ceh.ac.uk

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