ICP VEGETATION

28th Task Force Meeting

3 – 5 February 2015
Rome, Italy

Programme

&

Abstracts

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

Organizers:

ICP Vegetation Programme Coordination Centre
Centre for Ecology and Hydrology
Bangor, UK

Harry Harmens
Gina Mills
Felicity Hayes

Local organizers:

Fausto Manes
Elisabetta Salvatori
Lina Fusaro

Host: **Sapienza University of Rome**

PROGRAMME

Tuesday 3rd February, 2015

Location: Department of Environmental Biology

08:00 – 9:00 Registration and putting up posters

Session 1: 9:00 – 10:30 Plenary session ('Aula Giacomini') Chair: Fausto Manes

09:00 Welcome address – Local authorities.

09:15 *Harry Harmens* et al. – Overview of the achievements of the ICP Vegetation in 2014 and future workplan (2015-2017).

09:40 *Max Posch* et al. – Nitrogen and ozone interactions influencing forest growth - How to model on a European scale?

10:00 *Walter Seidling* et al. - ICP Forests – The programme and its current objectives.

10:20 *Angela Farina* – Italian forest monitoring activities within the ICP Forests network.

10:30 – 11:00 Coffee/tea and poster viewing

Session 2: 11:00 – 13:00 Plenary session ('Aula Giacomini')
Chair: Harry Harmens

11:00 *Katrina Sharps* et al. – ICP Vegetation ozone smart-phone App: Update on 2014 pilot study.

11:20 *Sabine Braun* et al. – Conclusions from the Epidemiology Workshop held in Basel 17/18-9-2014.

11:40 *Marina Frontasyeva* et al. – Preparations to the moss survey in 2015/2016: tentative plans in Europe and Asia.

12:00 *Eiliv Steinnes* – Atmospheric deposition of radionuclides monitored by moss analysis: Facts and fallacies.

12:20 *Fausto Manes* et al. - Green Infrastructures and Ecosystem Services: different vegetation types and air quality improvement in the Metropolitan area of Rome.

12.40 General discussion

13:00 – 14:00 Lunch

Session 3: **14:00 – 15:45 Two parallel sessions: Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')**

Session 3a: **Ozone: New developments in risk assessment for consideration for the Modelling and Mapping Manual** **Chair: Gina Mills**

14:00 *Rocio Alonso* et al. - Ozone critical levels for Mediterranean forests.

14:20 *Alessandra de Marco* et al. - The importance of soil water limitation in ozone risk assessment and its dependence by POD thresholds.

14:40 *Ignacio Gonzalez-Fernandez* et al. - Revision of ozone exposure experiments of annual Mediterranean pastures for setting ozone critical levels.

15:00 *Victoria Bermejo* et al. - Setting ozone critical levels for protecting horticultural Mediterranean crops: case study of tomato.

15:10 *Patrick Büker* et al. - New stomatal ozone flux dose-response relationships and critical levels for forest trees.

15:30 Discussion.

Session 3b: **Moss survey: Further developments and preparation 2015 survey** **Chair: Marina Frontasyeva**

14:00 *Eero Kubin* et al. - Development of specimen banking in Finland and distribution of reference material for heavy metal moss surveys.

14:20 *Winfried Schröder* et al. - Heavy metals and nitrogen concentrations in moss collected across Europe 2010 / 2011: statistical analyses covering four spatial scales.

14:40 *Michaela Meyer* et al. - Relevance of canopy drip for the accumulation of nitrogen in mosses across Europe.

15:00 *Hilde Uggerud* – POPs analysis at NILU.

15:15 Discussion on further preparations 2015 survey, including new database developments at JINR and linking with MossMet, relevance of measuring distance to nearest tree in forested areas.

15:45 - 16:30 **Coffee/tea and poster viewing (with authors present at poster)**

Session 4: **16:15 – up to 18:00 Two parallel sessions: Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')**

Session 4a: **Ozone: Ozone App and other field-based evidence of ozone effects** **Chair: Felicity Hayes**

16:30 *Pierre Sicard, Elena Paoletti* et al. - An epidemiological assessment of stomatal ozone flux-based critical levels for southern European forests.

16:50 Discussion on further field-based evidence of ozone impacts on vegetation: 1) Ozone App for recording incidences of ozone injury;
2) Ozone gardens in Europe (http://science-edu.larc.nasa.gov/ozonegarden/);
3) Additional evidence to update 2007 Evidence Report, including epidemiological data – what new data is available? (contributions to report?)
4) Ozone impacts on biodiversity (contributions to report?)

17:30 Continuation of discussion of changes to the Mapping Manual.

Session 4b: **Moss survey** **Chair: Trajce Stafilov**

16:30 *Pranvera Lazo, Flora Qarri* et al. - Survey of atmospheric deposition of Al, Fe, Li, Na, Ca, Mg and As, Cr, Ni, V, Zn in Albania by using moss biomonitoring and ICP-AES.

16:50 *Zdravko Spiric* et al. - Mercury concentrations in mosses in Croatia.

17:10 *Anatolii Dunaev* et al. - Environmental quality assessment of the town of Rodniki (Ivanovo region, Russia) by complex biomonitoring study.

17:30 If needed, further discussion on preparations for 2015 survey.

Wednesday 4th February, 2015

Session 5: **8:30 – 10:30** Two parallel sessions: **Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')**

Session 5a: **Ozone: Interactions with N and climate change**
Chair: Ignacio Gonzalez-Fernandez

08:30 *Gina Mills* et al. – An update from the EU FPVII ECLAIRE project.

08:45 *Patrick Büker* et al. - Further development of process-based flux models, taking into account other pollutants and climate change.

09:05 *Matthias Volk* et al. - Assessing soil organic carbon sequestration in an alpine pasture during seven years of increased atmospheric ozone and nitrogen deposition.

09:25 *Giacomo Gerosa* et al. - Ozone and nitrogen effects in oak and hornbeam young trees after two years of treatments.

09:45 *Per Erik Karlsson* et al. - Ozone impacts on vegetation in northern Europe - climate change impacts on the ozone sensitivity period and the change in ozone concentrations with height above ground.

10:05 *Lorenzo Cotrozzi* et al. - Evolution of ozone and drought stresses, singly or combined, in *Quercus cerris*.

10:25 General discussion

Session 5b: **Moss survey: Heavy metals** **Chair: Winfried Schröder**

09:00 *Trajce Stafilov* et al. – Environmental pollution with heavy metals in the republic of Macedonia.

09:30 *Alexander Alekseev* et al. - Forest ecosystems biodiversity assessment and inventory: case study for Karelian Isthmus of Leningrad region, Russia.

09:50 *Iselin Pettersen, Eiliv Steinnes* et al. - A study of emissions from adjacent metal industries using "moss bags".

10:10 General discussion.

10:30 – 11:00 Coffee/tea and poster viewing

Session 6: **11:00-13:00 Two parallel sessions: Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')**

Session 6 a: **Ozone: Further field-based evidence and climate change interactions**
Chair: Elisabetta Salvatori

11:00 *Kent Burkey* et al. - A new approach for studying ozone-temperature interactions in the field – system development and initial results for soybean.

11:20 *Alsayed Mashaheet* - Yield components of winter wheat as affected by leaf rust disease under elevated CO_2 and/or O_3.

11:40 *Zhaozhong Feng* et al. - Assessing effects of ambient ozone on snap bean cultivars by using ethylenediurea (EDU).

12:00 *Elena Gottardini* et al. - Ozone EFFORT, a five-year study on ozone exposure, flux and effects on vegetation in Trentino (northern Italy): a synthesis.

12:20 *Silvano Fares* et al. - Ozone sequestration and ozone-VOC interactions in a Holm oak peri-urban forest.

12:40 Discussion on remaining items from Tuesday and Wednesday morning.

Session 6b: **Moss survey** **Chair: Eiliv Steinnes**

11:00 *Stefan Nickel* et al. – Comparing results of modelling and mapping spatio-temporal trends of cadmium, mercury and lead accumulation in moss and natural surface soil throughout Norway derived by different statistical methods.

11:20 *Stefan Fränzle* et al. - Heavy metal biomonitoring in/by animals avoiding metabolic fractionation.

11:40 *Lucienne de Witte* et al. - Changes in ectomycorrhizal diversity and community composition along the nitrogen deposition gradient in Swiss beech forest.

12:00 *Mitja Skudnik* et al. – Mosses as biomonitors of trace elements in urban and peri-urban forests: preliminary results for the city of Ljubljana, Slovenia.

12:20 *Dinesh Saxena* et al. - Monitoring of heavy metals in ambient air from Garhwal Hills (India) using moss *Hypnum cupressiforme* Hedw.

12:40 General discussion.

13:00 – 14:00 Lunch

Session 7: **14:00-15:45 Two parallel sessions: Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')**

Session 7 a: **Ozone: modelling** **Chair: Zhaozhong Feng**

14:00 *Felix Leung* - Quantifying the impact of tropospheric ozone on crop productivity using JULES-Crop.

14:20 *Felicity Hayes* et al. - Combined effects of ozone and nitrogen on ecosystem services: experimental results and modelled future impacts.

14:40 *Angelo Finco* et al. - Above and below canopy ozone flux measurements at Bosco Fontana site. Implications for modeling and risk assessment.

15:00 *Yasutomo Hoshika* et al. – Stomatal conductance modelling for assessing ozone impacts on deciduous trees.

15:20 *Alessandro Anav, Alessandra De Marco* - Flux-based risk assessment in Europe with different approaches: a case study using CHIMERE model.

15:40 General discussion.

Session 7b: Moss survey **Chair: Harry Harmens**

14:00 *Harry Harmens* – Further general discussion and decisions/ recommendations to take forward to plenary on Thursday.

Discussion points:
- Further preparations 2015/16 survey
- Funding opportunities
- Web discussion forum, data processing, mapping
- Time schedule 2015 moss survey
- How to improve moss monitoring survey?

15:00 Option to have 5 min presentations per poster (including discussion time).

15:45 – 16:15 Coffee/tea and poster viewing

Session 8: 16:15-18:00 Two parallel sessions: Ozone ('Aula Giacomini'), Heavy Metals/N/POPs ('Aula C')

Session 8 a: Ozone: (Eco)physiology of trees **Chair: Giacomo Gerosa**

16:15 *Lina Fusaro* et al. - Ecophysiological response of *Quercus ilex* L. In urban and peri-urban forests of Rome: an Ecosystem Services perspective.

16:30 *Sabine Braun* et al. - Towards ozone uptake of oak (*Quercus robur*): sap flow measurements in a north-south gradient, including Bosco Fontana.

16:45 *Elisa Pellegrini* et al. - Reactive oxygen species and antioxidant machinery in *Liriodendron tulipifera* plants exposed to ozone.

17:00 *Gina Mills* - General discussion and decisions/recommendations to take forward to plenary on Thursday.

Session 8b: Moss survey

General discussion to discuss outstanding issues.

19:30 - 20:30: Concert of the "MuSA Classica" Sapienza Orchestra

20:30: Conference dinner, "Casa dell'Aviatore

Thursday 5th February, 2015

Session 9: 8:30 – 10:00 Plenary session ('Aula Giacomini')

Chair: Harry Harmens

- Reporting decisions and recommendations.
- ICP Vegetation work programme 2015 – 2017.
- Collaboration with other relevant bodies/organizations.
- Conclusions and review of the 28th Task Force Meeting.
- Next Task Force Meeting.
- Any other business.

10:30 – 18:00: Field excursion to Castelporziano Estate, summer residence of the President of the Italian Republic

Please bring with you your passport for identification and wear appropriate footwear for a field trip.

13:00 – 14:00: Lunch at the Castelporziano Estate

14:00 – 17:00: Field trip at Castelporziano Estate

18:00: Back at Sapienza University

List of posters

Group	Authors	Ttile
Moss	Maňkovská B., Izakovičová,Z., Oszlányi,J., Frontasyeva M.V., Ostrovnaya, T.M.	Critical evaluation of ecosystem pollution
	Koroleva Yu., Melnikova I., Mozharov S., Rafeenko A.	Bioindication of heavy metals atmospheric depositions in the southeast coast of the Baltic Sea (Kaliningrad region)
	Wilkins, K. and Aherne, J.	Heavy metal and nitrogen concentration in mosses in Irish Atlantic oak woodlands
	Cowden, P., Liang, T. and Aherne, J.	Moss as bioindicator of air pollution along an urban–agricultural transect in the Credit River Watershed, Southern Ontario, Canada
	Yulia Aleksiayenak. Marina Frontasyeva	Trace element atmospheric deposition study in Belarus
	Pranvera Lazo & Sonila Kane&Flora Qarri & Lirim Bekteshi	THE ENVIRONMENT SITUATION OF THE ALBANIAN COASTAL AREA BASED ON THE ASSESSMENT OF TRACE ELEMENTS DEPOSITIONS BY USING MOSSES AS BIOINDICATORS AND SEA EFFECT ON THIS ASSESSMENT
	L. Barandovski , M. V. Frontasyeva , T. Stafilov , R. Šajn	TRENDS IN ATMOSPHERIC DEPOSITION LEVELS OF SOME ELEMENTS IN MACEDONIA
	Goryainova Z.I., Vuković G., Aničić Urošević M., Vergel K.N., Ostrovnaya T.M., Frontasyeva M.V., Zechmeister H.	ASSESSMENT OF VERTICAL ELEMENT DISTRIBUTION IN STREET CANYONS OF BELGRADE AND MOSCOW USING MOSS TRANSPLANT TECHNIQUE
	Shetekauri S., Shetekauri T., Kvlividze A., Chaligava O., Kalabegeshvili T., Kirkesali E., Frontasyeva M.V., Chepurchenko O.E.	PRELIMINARY RESULTS OF ATMOSPHERIC DEPOSITION OF MAJOR AND TRACE ELEMENTS IN THE GREATER AND LESSER CAUCASUS MOUNTAINS STUDIED BY THE MOSS TECHNIQUE AND NEUTRON ACTIVATION ANALYSIS
	Dmitriev A.Yu., Frontasyeva M.V.	New database for moss surveys
Ozone	Grünhage et al.	a*POD* - approximate Phytotoxic Ozone Dose: a simplified concept to evaluate the O_3 risk at local scale
	C. Wu, I. Pullinen, S. Andres, G. Carriero, S. Fares, H. Goldbach, L. Hacker, T. Kasal, A. Kiendler-Scharr, E. Kleist, E. Paoletti, A. Wahner, J.Wildt, T.F. Mentel	Impacts of soil moisture on de-novo monoterpene emissions from European beech, Holm oak, Scots pine, and Norway spruce
	Carriero G, Hoshika Y, Fares S, Pignattelli S, Lazzara M, Giovannelli A, Emiliani G, Traversi ML, Brunetti C, Tattini M, and Paoletti E	A six-year EDU experiment on an O_3-sensitive poplar clone
	Evgenios Agathokleous, Costas J. Saitanis, Makoto Watanabe, Yasutomo Hoshika, Takayoshi Koike	CURRENT KNOWLEDGE ON EDU (ETHYLENE-DI-UREA), THE MOST EFFECTIVE ANTIOZONAN
	Costas J. Saitanis, Evgenios Agathokleous, Shafiqul M. Bari	Influence of ozone on R123-S158 snap bean biotypes under ambient air in Athens, Greece
	Madkour, Samia A.	Possible mechanisms for the protective action of the antiozonant Ethylenediurea(EDU) in ozone-sensitive and ozone-tolerant plant species
	Jingsong Sun, Zhaozhong Feng	Modelling effects of ozone on photosynthesis of flag leaves in winter wheat
	Feng Gao, Vicent Calatayud, Yulong Zhang, José Reig-Armiñana, Francisco García-Breijo, Zhaozhong Feng	RESPONSES OF FOUR COMMON URBAN TREES IN CHINA TO ELEVATED OZONE
	Borowiak Klaudia, Byczkowska Katarzyna, Hayes Felicity, Harmens Harry	Study on bean as a potential bioindicator of ozone and trace elements in ambient air
	Budka Anna, Borowiak Klaudia, Adamczak Joanna, Mleczek Mirosław	Tobacco as a potential bioindicator of ozone and trace elements in ambient air
	Tomasz Dziewiątka, Maria Drapikowska, Klaudia Borowiak, Felicity Hayes, Harry Harmens	Changes in anatomical and physiological parameters of bean (Phaseolus vulagris L.) under exposure to tropospheric ozone.
	Marando F., Fusaro L., Mereu S., Salvatori E., Lodato F., Ricci A., Manes F.	Structural characteristics of Quercus ilex L. as a tool for modelling pollutants removal in urban and peri-urban forests of Rome
	Muhammad Adrees, Muhammad Aamir Mehmood, Farhan Saleem, Fariha Jabeen, Muhammad Ibrahim and Shafaqat Ali	Impact of brick kiln emission on physiological and yield attributes of wheat in Punjab-Pakistan
	Gerosa G., Marzuoli R., Finco A., Monga R., Fusaro L., Salvatori E., Fares S., Kuzminsky E., Manes F.	A DOSE-RESPONSE RELATIONSHIP FOR YOUNG HOLMOAK TREES EXPOSED TO DIFFERENT LEVELS OF OZONE DURING ONE GROWING SEASON
	Adriana Basile, Sergio Esposito, Sergio Sorbo, Marco Lentini, Luigi Sanità Di Toppi	ULTRASTRUCTURAL AND FUNCTIONAL CHANGES INDUCED BY ATMOSPHERIC POLLUTION IN LUNULARIA CRUCIATA L. (DUMORT.)
	A. Rakmani, M. Bagard, J.F. Castell, A. Repellin, L. Leitao	Impact of ozone on field-grown maize using a free-air enrichment system
	Silli V., Salvatori E., Fusaro L., Galante G., Manes F.	Vegetation and Ecosystem Services: a pilot study to estimate PM air pollution removal in periurban Mediterranean forest of Catelporziano Estate
	Marcello Vitale, Chiara Proietti, Irene Cionni , Richard Fischer, Augusto Screpanti, Alessandra De Marco	THE IMPACTS OF CLIMATE CHANGE AND NITROGEN DEPOSITION ON FOREST HEALTH CONDITION
	Changey F., Bagard M., Souleymane M., Lerch T.Z.	Impacts of elevated ozone and temperature on wheat rhizosphere microbial communities
	Terenzio Zenone, Federico Brilli, Donatella Zona, Reinhart Ceulemans	Fluxes of ozone and isoprene in a poplar plantation for bioenergy production
	Fumagalli I. and Gruening C.	Assessment of potential drivers for the release of NO from the soil in a subalpine forest

Abstracts

Oral

Presentations

FOREST ECOSYSTEMS BIODIVERSITY ASSESSMENT AND INVENTORY: CASE STUDY FOR KARELIAN ISTHMUS OF LENINGRAD REGION, RUSSIA

Alexander Alekseev

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Regular grid of permanent sample plots (PSP) of ICP-Forests monitoring system was used for forest ecosystems biodiversity assessments and inventory of Karelian Isthmus of Leningrad region with the total area of 617,6 thousands hectares. The supplementary features were added to the PSP structure to conduct biological diversity census: eight sample plots 1x1 m for geo-botanical description; two sample plots of 5x5 m each for description of the PSP's undergrowth; one 25x25 m plot for coarse woody debris estimations; four soil inventory pits. The total number of PSP amounted to 248. Total data used are as following:

- 1,984 geo-botanical descriptions of vegetation belonging to herbaceous-shrubby and moss-lichen layers made on 1x1 m sample plots;
- 496 descriptions of undergrowth on 5x5 m sample plots;
- 178 descriptions of woody debris on 25x25 m sample plots (the description is systematically conducted on each plots);
- 496 descriptions of soil inventory pits.

General statistical indicators characterizing forest land cover diversity were calculated. Statistic indicators of α-diversity for the Karelian Isthmus forest vegetation cover have the following values:

m (mean number of species per PSP) = 26 species
σ (standard deviation) = 9.5 species
v (variation coefficient) = 36.5%
P (deviation amplitude) = 60 – 7 = 53 species

Alpha-diversity statistics significantly varies over the territory of the Karelian Isthmus. Amplitude of deviation in species variety amounts to 53 species that is twice as much as the mean value. The largest species variety exceeds almost by 9 times the smallest one. Forest plant species diversity on the Karelian Isthmus is relatively small, ranging from 15 to 35 species in almost 2/3 of the cases that is typical for the south taiga zone.

All forests on study area have a lichen-moss layer. Relative ground coverage by lichens and moss on 39.9% PSP is 51% and more, on 25.2% is 26-50% and on 34.9% is less than 25%. Total number of species of moss and lichens revealed on PSP accounts for 35 and gives significant input into total forest ecosystem biodiversity.

Simpson index calculated separately for 4 forest ecosystem layers which indicates the probability that two randomly selected plants belong to the same species gives following results: tree – 0.74, undergrowth – 0.62, grass-shrubby – 0.35 and moss-lichen – 0.49. These illustrate the maximum input into forest ecosystem plants biodiversity of grass-shrubby and moss-lichen layers. The high level of dominance in tree layer is natural for the taiga zone.

Sample plots distribution (or share) according to species diversity gradation is well described by standard curve of normal distribution (determination coefficient of the curve being 95.2%). Standard of alpha diversity for forest ecosystems should be considered to be the mean value of alpha diversity for each forest type group – *m*; standard deviation - *σ,* and standard curve are analytical tools for assessing deviations from the standard.

All PSP locations are fixed using GPS technology these allows biodiversity assessments at the same place in the next years for biodiversity trends estimations and consist the frame for systematic biodiversity inventory.

OZONE CRITICAL LEVELS FOR MEDITERRANEAN FORESTS

Rocío Alonso*[1], Giacomo Gerosa[2], Ángela Ribas[3], Vicent Calatayud[4], María Díaz de Quijano[3], Susana Elvira[1], Esperanza Calvo[4], Ricardo Marzuoli[2], Josep Peñuelas[3], Martina Pollastrini[5], Filippo Bussotti[5], Simone Mereu[6], Lina Fusaro[7], Angelo Finco[2], Ignacio González-Fernández[1]

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Ozone (O_3) is the most important and pervasive air pollutant in the Mediterranean region where climatic conditions favor O_3 photochemical formation and persistence. O_3-induced effects have been reported on the physiology and growth of Mediterranean forest species. However, discrepancies exist between the observed and the predicted O_3 effects on Southern European forests based on current O_3 critical levels. This discrepancy is likely to be explained by the inadequacy of the critical level and/or the inherent higher O_3 tolerance of Mediterranean vegetation. A review of O_3 exposure experiments performed with Mediterranean tree species has been carried out to address this issue. Only those experiments estimating O_3-induced effects on tree biomass or growth of evergreen tree species growing under Mediterranean climate conditions were considered. A database of 16 experiments including 7 different tree species and 3 experimental sites was used to derive exposure- and flux-based response functions. Among the species considered, one species was a conifer (*Pinus halepensis*) and 6 were broadleaf evergreen species (*Quercus ilex* ssp *ilex*, *Q. ilex* ssp *ballota*, *Q. coccifera*, *Ceratonia siliqua*, *Olea europea*, *Arbutus unedo*). All the experiments were performed with seedlings growing in open top chambers exposed to different O_3 treatments. The control treatment in all the experiments was charcoal-filtered air. Four experiments included water stress treatments. The length of the experiments varied between 0.3 to 3 years, with 12 out of 16 experiments considering about one year or longer. Exposure and dose-response function were derived from experiments including at least 60% of the growing period: 12 out of 16 experiments. Ozone-induced effects were better related to stomatal fluxes than to O_3 exposure expressed as AOT40, when treatments with drought stress were included. Thus drought stress needs to be considered for ozone flux estimations in water-limited ecosystems. Interestingly, drought stress did not necessarily protect plants from O_3 effects. Using a threshold value for estimating ozone stomatal fluxes did not improve the response function. The resulting response functions were compared with published results obtained with 5 deciduous species growing under Mediterranean climate conditions and a conifer species characteristic of Southern-Europe mountain areas. The results indicate that Mediterranean tree species are more tolerant to O_3than species from more humid biomes, yielding higher O_3 critical levels than those reported in the Mapping Manual. The results indicate that different O_3 critical levels should be used for damage risk assessment in Europe depending on vegetation types.

Acknowledgements
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FLUX-BASED RISK ASSESSMENT IN EUROPE WITH DIFFERENT APPROACHES: A CASE STUDY USING CHIMERE MODEL

Anav A. and De Marco A.

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Air pollutants provide an unfavorable condition for vegetation growth and may affect plant's metabolism, ecosystem structure and functions in different ways. Among common air pollutants, O3 is probably the most damaging to forest vegetation frequently reaching high concentrations over large regions of the world.
The global mean concentration of near surface O_3 has been increasing during the last years and it is expected to increase significantly through the next century, although the magnitude of the increase depends on the particular emission scenario chosen. Therefore, it is mandatory to improve our knowledge on the adverse effects of O_3 on terrestrial vegetation and improve the land carbon models in order to account and qualify the O_3 injury.
We developed a multi-model framework to assess the impact of ozone on European vegetation at a fine spatial resolution (12 km) for the years 2000-2005. Our assessment is based on PODy and AOT40 indices, computed using the Emberson's parameterization to infer the stomatal conductance. Meteorological forcing, needed to estimate the temperature, water, and radiation limitation on the stomatal conductance, are calculated using the WRF 3.6 model, while the O_3 concentrations are simulated through the CHIMERE model.
Our results indicate that the most sensitive region to O_3 injuries are over Northern Europe (mainly France) and central Italy, while Mediterranean forest of Spain do not suffer any strong O_3 damage because of water limitation during O_3 peaks.
Although our simulated annual O_3 concentrations are in agreement with EMEP data, the comparison of POD1 shows large discrepancies between our framework and EMEP results.

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TOWARDS OZONE UPTAKE OF OAK (QUERCUS ROBUR): SAP FLOW MEASUREMENTS IN A NORTH-SOUTH GRADIENT, INCLUDING BOSCO FONTANA

Braun, S.[1)], Gerosa, G.[2)], Finco, A.[2)]

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Sap flow measurements were successfully used for validation of the DO_3SE model in beech. However, a closer data analysis suggested that the stomatal functions for temperature and humidity depend on local climate. The aim of the present study was to 1) validate the stomatal functions of the DO_3SE model for oak and 2) analyse if there are local differences in this stomatal functions which can be attributed to climate. Therefore, three plots with *Quercus robur* were selected in a North-South gradient: one in Northwestern Switzerland close to Basel, one in Southern Switzerland (canton Ticino) and one in Italy (Po valley: Bosco Fontana). The latter plot allows to compare the water flux in the stem with total flux measured by Eddy covariance.

The first results suggest that also in oak the stomatal functions depend on local climate. However, more measurements are needed as the summer 2014 was very rainy.

CONCLUSIONS FROM THE EPIDEMIOLOGY WORKSHOP HELD IN BASEL 17/18.9.2014

Braun, S.[1)], Schindler, C.[2)], Rihm, B.[3)], Achermann, B.[4)]

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A workshop on epidemiological analysis of air pollution effects on vegetation was held in Basel from 16 to 17 September 2014. The workshop was attended by participants from four countries. It was hosted by the Swiss Federal Office for the Environment and chaired by Beat Achermann. Presentations were given by Beat Rihm on mapping and modelling aspects, Sabine Braun on ozone flux and stem increment of beech, Christian Schindler on statistical methods, Per Erik Karlsson on stem increment of Norway spruce and by Alessandra de Marco on a field survey of ozone symptoms.

The conclusions state that epidemiological analysis is a powerful approach for disentangling and quantifying the contributions of different predictor variables to an overall effect like e.g. growth. It requires, however, a sufficiently large number of observations at large spatial and/or temporal scale, along with sufficiently pronounced gradients of air pollutants and modifying factors. It was suggested that the recommendations for epidemiological studies should be compiled to a background paper.

A brief workshop report and the presentations can be downloaded from the ICP vegetation website (http://icpvegetation.ceh.ac.uk/events/workshop.html).

A NEW APPROACH FOR STUDYING OZONE-TEMPERATURE INTERACTIONS IN THE FIELD – SYSTEM DEVELOPMENT AND INITIAL RESULTS FOR SOYBEAN

Kent O. Burkey, Samuel J. Ray, Walter A. Pursley, and Richard W. Zobel

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Predicting the impacts of air pollution and climate change on vegetation requires understanding of the interactions between elevated air temperature and atmospheric gases such as ozone and carbon dioxide. Imposing elevated temperature treatments while manipulating gas concentrations remains a technological challenge, particularly for field studies. To this end, we have developed and tested an air exclusion system (AES) for exposing plants to combinations of elevated temperature and ozone in field plots. Each AES plot consists of open-top chamber bottom panels in parallel to form a 3m x 10m treatment area (Figure 1). Modified open-top chamber fan boxes provide charcoal-filtered air that is heated prior to distribution within the plot through holes in the inner wall of the double-walled panels. Air is heated by a combination of electrical resistance heaters mounted inside the fan box and solar heated water passed through heat exchangers placed in-line with the air flow inside the fan box. To compensate for the decrease in relative humidity upon warming the air, the heated air is passed through a misting system inside the modified fan boxes prior to distribution throughout the heated plots. Ozone is added to the air stream as the final step prior to distribution into the plot. The AES system was tested during 2014 using soybean as a test crop. Treatments were a charcoal-filtered control (CF), heated CF (CF+H), elevated ozone (O3), heated elevated ozone (O3+H), and ambient air (AA) plots without the AES structure.

Figure 1. The air exclusion system for an elevated temperature plot

The AES system provided an elevated temperature across the season of approximately +4°C (Figure 2) and excellent ozone control including a sub-ambient CF treatment (Table 1).

Figure 2. The 24-hour average temperature (°C) in AES plots in 2014

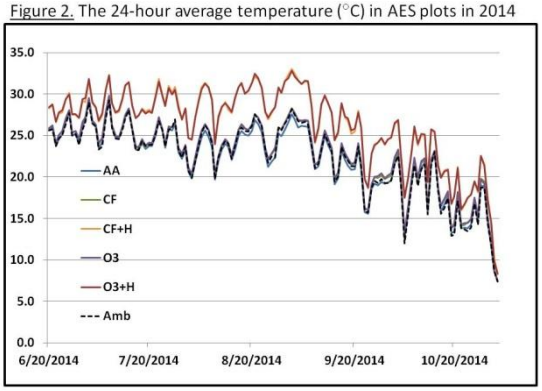

Table 1. Seasonal ozone concentrations in AES plots during 2014 with soybean as the test crop

Treatment	12-hour mean (ppb)	AOT40 (ppb-hours)
AA	32	2781
CF	15	26
CF + H	18	101
O3 (60 ppb 12-hour mean target)	52	20789
O3 + H	52	21191

EVOLUTION OF OZONE AND DROUGHT STRESSES, SINGLY OR COMBINED, IN *QUERCUS CERRIS*

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The objective of this study was to evaluate the impact of ozone (O_3) and drought, either singularly or jointly applied, on the physiological and biochemical traits of the Mediterranean tree species *Quercus cerris*. Three-year-old saplings were subjected to moderate drought (daily irrigated with 30% of effective evapotranspiration) and/or fumigated with 100 ppb of O_3 (5 h d^{-1}) for 77 days, in order to simulate a 2050 environmental scenario. After 28 days and at the end of the stresses exposure the following parameters were analysed: *i*) leaf water status and membrane integrity; *ii*) diurnal courses of photosynthetic process; *iii*) osmolytes and accessories pigments content. Under drought (alone or in combination with O_3), 42 days from the beginning of the treatment, plants showed lateral and tip yellow-brown necrosis in the youngest fully expanded leaves. At the end of the fumigation, no O_3 leaf injury was observed, but all plants (with exception of controls) showed a marked phylloptosis. Drought stress (single and combined) impaired plants performances already after 28 days. Predawn leaf water potential ($PD\Psi_w$), malondialdehyde (MDA) and proline levels were more affected by drought applied individually than in combination [more than 5-fold *vs* 3-fold lower in comparison to controls, +11 *vs* +4%, +112 *vs* +45%, respectively]. The circadian patterns of photosynthetic process were impaired similarly at the quali-quantitative level. Leaf carbon dioxide (CO_2) assimilation rate (A) decreased (-65% compared to control, as daily mean) due to both stomatal [-67% of stomatal conductance (g_s)] and biochemical limitations [intercellular CO_2 concentrations (C_i) showed unchanged or higher values during the whole day], same as the maximum (F_v/F_m) and effective (Y) quantum yields of photosystem II (-9 and -41%, respectively). On the other hand, in O_3-stressed plants, similar responses were observed only after 77 days of the exposure: -80% of $PD\Psi_w$ values (compared to controls, as daily mean); +17% of MDA concentrations; proline content from lower values (observed after 28 days) increased to constitutive levels; -68% of A and -70% of g_s; C_i and F_v/F_m, unchanged; -13% of Y values, (only photoinhibiton was observed). Moreover, at the end of the treatment, the effects of coupled stresses were stronger than that of drought applied individually in terms of water status, lipid peroxidation and proline content while the circadian patterns of photosynthesis continued to be affected similarly at the quali-quantitative levels. Differential abscisic acid (ABA) evolutions, strictly twinned with its precursors (neo- and violaxanthin), were observed during the summer. After 28 days of treatment, the content of this phytohormone rose only in plants subjected to drought (+143%), while an increase of neoxanthin was observed in O_3 and combined ones (+15 and +31%, respectively). At the end of the exposure, ABA concentration significantly increased in O_3 (single and in combination) stressed plants (+250 and +64%, respectively), while violaxanthin content decreased (-32 and -47%, respectively). In conclusion, in *Q. cerris*: *i*) drought stress (single and combined) should be considered more harmful than O_3, although it should be mitigated by this pollutant for a limited time; *ii*) drought and combined stresses impaired similarly the diurnal pattern of photosynthetic processes at the quali-quantitative levels, and *iii*) the osmolytes (in particular ABA) could play a key role in the responses to environmental constrains.

Acknowledgment
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THE IMPORTANCE OF SOIL WATER LIMITATION IN OZONE RISK ASSESSMENT AND ITS DEPENDENCE BY POD THRESHOLDS

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Stomatal ozone flux is considered an optimal metric to evaluate O_3 effects on vegetation, and can be calculated over the growing season by the DO_3SE model. The resulting Phytotoxic Ozone Dose (PODY) incorporates the effects of environmental variables on stomata and of plant detoxification ability, by developing species-specific parameterizations and assuming no injury below a threshold Y. Most of previous PODY-based risk assessments, however, have not included soil water content (SWC), as this limitation is considered negligible in most climates. We modelled input data by WRF-CHIMERE for 14,546 grid-based forest sites distributed in temperate and Mediterranean climates in Southern Europe, and calculated PODY either with or without water limitation and by using four Y thresholds. Excluding SWC caused a serious overestimation of PODY. The error increased with increasing Y thresholds (by 82%, 166%, 471% and 5582% with Y = 0, 1, 2 and 3, respectively). The errors were lower in temperate species (*Pinus cembra* 52-628%, *P. sylvestris* 60-743%, *Abies alba* 60-735%) and higher in Mediterranean species (*P. pinaster* 90-2147%, *Quercus suber* 107-3755%, *P. halepensis* 102-4456%, *P. pinea* 110-5435%). The highest error was recorded for the temperate species *Fagus sylvatica* at POD3 (26,756%). Including SWC in any DO3SE simulation and using the lowest Y threshold, i.e. POD0, are thus recommended.

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Changes in ectomycorrhizal diversity and community composition along the nitrogen deposition gradient in Swiss beech forests

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Environmental change has serious implications for functional biodiversity in temperate beech forests that cover large parts of Swiss lowlands. Many forest trees depend on ectomycorrhizal fungi for nutrient uptake, but increases in nitrogen deposition due to environmental pollution may alter fungal communities and their assets to the symbiosis. Therefore, we investigated the changes in ectomycorrhizal diversity and community composition along a gradient of modelled nitrogen deposition (ranging between 15 and 50 kg N/ha/yr) using molecular techniques. In 15 permanent forest observation plots, ectomycorrhizal colonization of root tips and species richness were significantly reduced, from 58 species at lowest to 25 species at highest nitrogen deposition. Community are dominated by different fungal species and community composition shifts along the nitrogen deposition gradient. We also explore whether the observed differences in the nutritional status of the trees can be related to distinct ectomycorrhizal community changes. A shift in exploration types is a first hint why trees suffer phosphorous limitation. We now investigate activity of ectomycorrhizal species and presence of extrametrical mycelium to find confirmation.

ENVIRONMENTAL QUALITY ASSESSMENT OF THE TOWN OF RODNIKI (IVANOVO REGION, RUSSIA) BY COMPLEX BIOMONITORING STUDY

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The results on briomonitoring of atmospheric deposition of trace elements in Ivanovo Region, Central Russia, in moss survey 2010/2011 are reported. A "hot spot" was revealed in the town of Rodniki, the textile cluster of the Ivanovo Region in the nearest future.

To investigate this "hot-spot" an additional studies were performed. Samples of moss and soil from the background sites of the district of Rodniki were collected in 2010. In 2011 and 2013 samples of moss and soils were taken from the vicinity of the town of Rodniki. In addition, samples of snow were collected in spring of 2014. The analysis of fluctuating asymmetry of the leaves of birch (*Betula pendula*) was also made.

A total of 47 elements were determined in moss and soil samples by two complementary analytical techniques, neutron activation analysis performed at JINR, Dubna, and atomic absorption spectrometry in ISUCT, Ivanovo. GIS distribution maps of element-pollutants and some statistical data treatment are presented. The analysis of fluctuating asymmetry was made in IvSU, Ivanovo.

The obtained data justified a significant degree of air and soil pollution in the district of Rodniki. The most important contaminants in soil are V, Cr, Mn, Zn, Co, and As, while for air they are Pb and Cd. The spatial distribution of Pb, Cd, and Zn in snow is in good agreement with the moss one. The main source of lead and cadmium is high way motor transport in the town of Rodniki. Most probable sources of other elements (especially in soil) are metal working and asphalt plants.

OZONE SEQUESTRATION AND OZONE-VOC INTERACTIONS IN A HOLM OAK PERI-URBAN FOREST

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Mediterranean forest ecosystems are exposed to high loads of anthropogenic pollutants and are among the most threatened ecosystems on Earth by climate changes. In order to fully explore plant-atmosphere interactions under environmental stress, bi-directional exchanges of Volatile Organic Compounds (VOCs), nitrogen oxides (NOx), CO_2, water, and ozone were investigated in a Mediterranean Holm oak forest in Castelporziano presidential estate, a peri-urban forest near the coast of Tyrrhenian sea, 20 km from Rome downtown, Italy. Two intensive field campaigns were carried out between January 2012 and August 2014 to explore seasonal dynamics of fluxes under different climate conditions and physiological activity of plants.

VOCs were measured using a proton transfer reaction - mass spectrometer (PTR-MS). These included biogenic products as isoprenoids (BVOC – isoprene, monoterpenes), oxygenated BVOC (OVOC – methanol, acetaldehyde acetone) and VOC of anthropogenic origin (AVOC – acetonitrile, benzene, hexenal, toluene, xylenes). Our measurements comprise high frequency (10 Hz) sampling of VOC concentrations along a 5-level gradient from soil-level to above the canopy. We used eddy covariance technique to calculate half-hour fluxes of all the above mentioned gases, while gradient measurements were used to estimate within-canopy source and sink distribution by applying an Inverse Lagrangian Transport Model. Moreover, laboratory experiments were carried out using Holm Oak saplings and enclosure systems to simulate stress condition led by high ozone and drought. In particular, the objectives of laboratory experiments were 1. Quantify the capacity of Oak leaves to sequestrate oxidation products between VOC and ozone, and 2. Estimate the capacity of emitted VOC to form ozone into the atmosphere through photochemical reactions. Data collected in the field and through laboratory experiments served to parameterize a novel multi-layer model to predict greenhouse gas and pollutant exchanges between urban plant and the atmosphere.

Results showed that low temperatures lead to almost negligible BVOC fluxes during cold seasons. Summer fluxes were largely represented by BVOC (mainly monoterpenes) and were recorded in the central hours of the day in response to high light and temperature. In the same periods, high amount of ozone was sequestrated by plants mainly through stomatal uptake. Laboratory studies showed that leaves can remove products of VOC oxidation into the atmosphere. However, the ozone forming potential of emitted VOC is high and must be considered for computing a realistic ozone balance in a VOC-limited environment.

The model showed good agreement when predictions were compared with measured data. We discuss here the potential of our model to calculate bi-directional fluxes of trace gases in the soil-plant-atmosphere continuum as a main step toward complete evaluation of ecosystem services provided by forests.

ASSESSING THE EFFECTS OF AMBIENT OZONE ON SNAP BEAN CULTIVARS BY USING ETHYLENEDIUREA (EDU)

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Four cultivars of snap bean (*Phaseolus vulgaris L.*), lines 'S156' (O_3-sensitive) and 'R123' (O_3-tolerant), and two Chinese cultivars, 'DDW' (O_3-sensitive) and 'NX816' (O_3-tolerant), were selected to study the effects of ambient ozone concentration at a cropland area around Beijing. Half of the plants were treated with 400 ppm of the antiozonant ethylenediurea (EDU), applied biweekly as a foliar spray from leaf expansion to pod harvest, and the other half with water (control). During the growing season period, the 8h (9:00-17:00) average ozone concentration at the experimental site was very high, about 71.3 ppb, and the AOT40 was 29.04 ppm.h. All cultivars showed foliar injury, but O_3-sensitive cultivars exhibited much more injury than O_3-tolerant ones. Compared with control treatment, 400 ppm EDU significantly alleviated foliar injury and increased photosynthesis rate and Vc_{max}, but only in O_3-sensitive cultivars and not in O_3-tolerant cultivars. Plants treated with EDU had less MDA contents and higher total antioxidant capacity (TAC) than control plants. At harvest stage, both the above-ground biomass and the below-ground biomass increased significantly in EDU-treated plants of all cultivars. However, only O_3-sensitive cultivars showed a significant increase in seed and pod yields after EDU treatment. Therefore, EDU effectively protects sensitive cultivars from ambient O_3 damage, while protection on O_3-tolerant cultivars is limited. From these results, EDU can be regarded as a useful tool to assess the effects of ambient O_3 concentration on sensitive species.

Key words: Ambient ozone, Ethylenediurea, Snap bean, Foliar injury, Photosynthesis, Yield

ABOVE AND BELOW CANOPY OZONE FLUX MEASURENTS AT BOSCO FONTANA SITE. IMPLICATIONS FOR MODELING AND RISK ASSESSMENT.

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In the framework of the intensive field campaign of the ECLAIRE project, in June and July 2012, ozone, sensible heat and momentum fluxes were measured at four different heights over a 26 m tall mixed oak-hornbeam forest, at the Bosco Fontana site, in the Po valley (I). At each level (41 m, 32 m, 24 m and 16 m) a sonic anemometer and a fast ozone analyser were mounted while ozone concentrations were measured by an absolute UV analyser.
Ozone concentrations were measured at 0.15 m by means of another UV photometer as well as other meteorological parameters were measured at the top of the tower and along the vertical profile.
Since fast ozone measurements were collected with different instruments, preliminary analysis (despiking, instantaneous rotations, WPL corrections, frequency loss corrections and calculation of the random error) were performed to properly compare the flux measurements.

Even if the main aims of this field campaign were the description of the deposition processes within and above canopy and the test of the constant flux hypothesis, interesting features for the ozone risk assessment emerged. In fact, ozone deposition was almost constant until midday for the three upper levels while an enhancement of the fluxes was observed at 24 m. This fact was strictly linked with the in-canopy dynamics: a greater heating of the canopy was observed in the afternoon, leading to the formation of an inversion at this level. This inversion divided the in-canopy air volume into two layers: the lower one with a stable stratification and the upper one with a turbulent regime. These results are in contrast with the widely used "big-leaf approach, usually employed for the estimation of the ozone stomatal uptake by the studied ecosystem. This methodology states that the forest is equivalent to a big-leaf laying at $d+z_0$, that is the height at which ozone concentration is supposed to be null and in our case should be around 19 m. Our results showed that at 16 m, the lowest flux level, ozone concentrations were almost equal to the levels above for the first part of the day and even at 0.15 m were substantially different from zero for large part of the day. This results highlight the need for new methodologies for the estimation of the ozone risk assessment, other approaches for estimating the stomatal ozone uptake will be showed too.

PREPARATION OF THE MOSS SURVEY IN 2015/2016: TENTATIVE PLANS FOR EUROPE AND ASIA

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A brief review of the current status in preparation to the moss survey 2015−2016 is given. In agreement with the long-term strategy of the LRTAP Convention to enhance participation and improve air quality in the Eastern Europe, the Caucasus, Central Asia and South Eastern Europe, efforts to extend the moss survey for the former republic of the USSR such as Armenia, Azerbaijan, Georgia, Moldova, Kazakhstan, and Uzbekistan were successfully undertaken. Around 15 teams are formed in Russia to cover with moss sampling Northern and Central Russia, Western Siberia, and Far East of Russia (Kamchatka and Sakhalin). JINR will continue support for the moss survey program in its member states: Bulgaria, Slovakia, Poland, Romania, Mongolia, Vietnam, as well as in non-member states: Albania, Croatia, Hungary, Thailand, South Korea, and China. Up-to-date 36 countries expressed their desire to participate in the coming moss survey. In spite of the growing interest in assessment of the deposition of persistent organic pollutants (PAHs, PCBs, PBDEs, dioxins, PFOS, etc.) using moss, only a limited number of the Western European countries intend to determine POPs. Radioecological laboratories in JINR (Dubna, Russia), Institute of Nuclear Physics (Alma Ata, Kazakhstan), University of Novi Sad (Serbia), Bratislava University (Slovakia) and Opole University (Poland) will be used to measure natural and man-made radionuclides (^{137}Cs, ^{210}Pb, etc.) under individual agreements with the interested countries. Some details will be given on the newly established database for storage of information about the European and Asian moss survey, conducting and storing analytical results on heavy metals, nitrogen, persistent organic compounds and radionuclides based on moss analysis. The planned interlaboratory comprison on trace element determinations in the Finnish moss reference samples M2 and M3 will be discussed.

ECOPHYSIOLOGICAL RESPONSE OF *QUERCUS ILEX* L. IN URBAN AND PERIURBAN FORESTS OF ROME: AN ECOSYSTEM SERVICES PERSPECTIVE.

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Green Infrastructures (GIs), such as urban forests, deliver ecosystem services (ESs) and benefits. To quantify them, information is needed on how these services depend on, species-specific physiology, biodiversity and biomass distribution patterns. Among Ess provide by GIs, the amelioration of urban air quality through the removal of air pollutants such as tropospheric ozone, is of particular importance, especially in the Mediterranean area. Knowledge on plant physiology in urban and periurban areas may play an important role in improving the quality of life in urban environments. The present study was carried out in the metropolitan area of Rome, considering an urban (Villa Ada) and a periurban forest (Castelporziano Estate). Both forests are dominated by *Quercus ilex* L., which has been chosen for its wide natural distribution in the Mediterranean Basin, as well as for its widespread use in urban contexts. The two studied sites differed in environmental condition, as well as forest structure and management, resulting in different trends of the considered functional parameters (leaf gas exchanges, photosystems functionality and plant water status). During spring, gas exchanges were lower in urban than in periurban forest, due to higher air temperature and Vapour Pressure Differences in the latter site. During summer, instead, in the periurban area the functionality of *Q. ilex* was affected by drought stress, which did not occur in the urban forest due to higher summer rainfalls as well as periodic irrigations. The water use efficiency was basically lower in the urban park than in the periurban forest, as well as the photosystem functionality (PSII and PSI). Differences in the intensity of the main phonological phases were also highlighted. In summary, understanding how gas exchange responds to environmental factors can allow to quantify stomatal ozone removal. Moreover our results point out that the GIs in the metropolitan area of Rome fulfill a complementary role in the ESs provision in relation to the ozone removal, and the resulting air quality improvement.

OZONE AND NITROGEN EFFECTS IN OAK AND HORNBEAM YOUNG TREES AFTER TWO YEARS OF TREATMENTS

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An Open-Top Chambers (OTC) experiment with ozone enrichment and increased nitrogen deposition was performed during two consecutive growing seasons (2012 and 2013) in Northern Italy on young trees of *Quercus robur* and *Carpinus betulus*.
The experiment followed a split-plot design with 3 randomized blocks and two factors: ozone concentration as the main factor, at 4 different levels (CF-45%, NF, NF+35%, NF+70%), and nitrogen irrigation (NDep) as a nested factor, at 2 different levels (tap water for control, tap water +NDep of 70Kg of N*ha*y^{-1}). These treatments were applied for two consecutive growing seasons using 12 OTCs.
In both years stomatal conductance (g_s) measurements and CO_2 assimilation response curves were performed throughout the season to assess the impacts on physiological and photosynthetical parameters. Half of the plants was harvested at the end of 2012 season, while the remaining half was harvested at the end of 2013. Total biomass and root/shoot ratio were assessed to estimate the effects of both stresses and their interaction
After the second year of treatments, a general significant positive effect of nitrogen deposition on biomass production was found in both species. This biomass increase was particularly intense in *C. betulus* (+76% and +65% of the total and roots biomass respectively, $p \leq 0.01$). *Q. robur* showed more marked responses to O_3 than *C. betulus* in the -Ndep conditions, with a 10% (n.s.) and a 12% ($p \leq 0.05$) of reduction of the total and root biomass respectively, due to O_3 enriched treatments. This response was also found in the plants subjected to increased NDep (-8% for both total and roots biomass, n.s.). Hornbeam showed no significant effects on biomass in O_3 enriched treatment when no NDep was added. However, +NDep treatments made hornbeam more susceptible to O_3 damages, with a 24% (n.s.) decrease in roots biomass and a 20% ($p \leq 0.05$) decrease in shoots in O_3 enriched conditions.
Looking at g_s as a possible physiological determinant of the plants' response to O_3, we found that O_3 lead to a 19% ($p \leq 0.05$) decrease of g_s in oak plants grown in –Ndep conditions that showed a 10% of reduction in total biomass. This response to O_3 is confirmed in +NDep treatments (-14% in g_s, -8% in total biomass). In hornbeam without NDep addition, O_3 caused a slight reduction on g_s (-9%, n.s.) with no significant variation on the biomass production (+5%, n.s.). Therefore, the relatively higher sensitivity to O_3 of oak, with respect to hornbeam, could be explained by the higher reduction of g_s and by the consequent reduction of CO_2 assimilation.
NDep caused a significant increase of g_s in hornbeam (+19%, $p \leq 0.001$) that lead to an increased ozone uptake in the O3 enriched plants, which showed a general reduction in biomass (-20% in shoots biomass, $p \leq 0.05$, -24% in roots biomass, n.s.). On the contrary, oak plants didn't show any significant effects of NDep treatments on g_s.
The general decrease of g_s in both species caused by O_3 suggests the need to include an $f(O_3)$ modifying function in the stomatal conductance models which will be defined for these two species. Some of the biomass responses are partially in disagreement with the results of the first year of experiment, likely for the presence of a carry over effect. This fact highlights the importance of performing long-term experiments (more than 1 year) for the investigation on O_3 and nitrogen effects on biomass.

SETTING OZONE CRITICAL LEVELS FOR PROTECTING HORTICULTURAL MEDITERRANEAN CROPS: CASE STUDY OF TOMATO

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Seven experiments carried out in Italy and Spain have been used to parameterising a stomatal conductance model and establishing exposure- and dose-response relationships for yield and quality of tomato with the main goal of setting O_3 critical levels (CLe) (González-Fernández *et al*., 2014). CLe were set (with confidence intervals between brackets) considering only the sentive cultivars at an accumulated hourly O_3 exposure over 40 nl·l^{-1}, AOT40=8.4 (1.2, 15.6) ppm.h and a phytotoxic ozone dose above a threshold of 6 nmol·m^{-2}·s^{-1}, POD6=2.7 (0.8, 4.6) mmol·m^{-2} for yield.These values are higher than those currently indicated in the Mapping Manual for yield (6 ppm h and 2 mmol·m^{-2}) (CLRTAP, 2014). A new threshold based on quality (fruit sugar content) was stablished: AOT40=18.7 (8.5, 28.8) ppm.h and POD6=4.1 (2.0, 6.2) mmol·m^{-2} for quality, both yield and quality indices performing equally well.

These CLe, derived for sensitive tomato cultivars, should not be applied for quantifying O_3-induced losses at the risk of making important overestimations of the economical losses associated with O_3 pollution. CLe confidence intervals provide information on the quality of the dataset and should be included in future calculations of O_3 CLe for improving current methodologies.

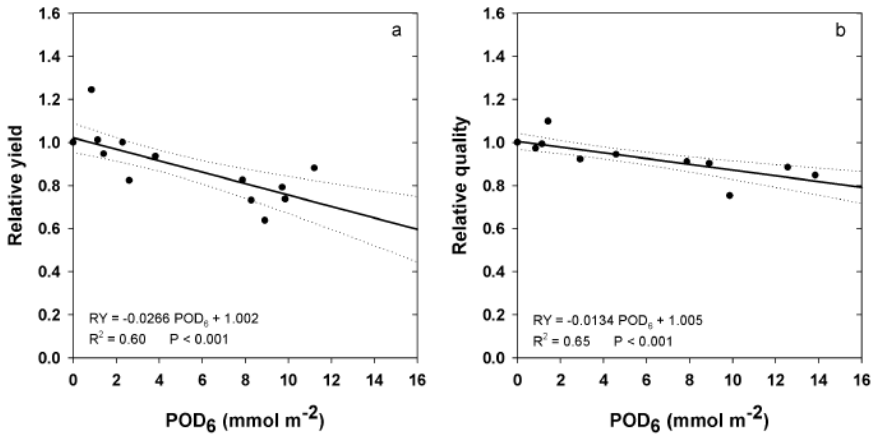

Figure1. *Dose-response relationships for tomato fruit yield (a) and fruit quality (b). The solid and dashed lines depict the linear regression and the 95% confidence intervals of the regression respectively*

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REVISION OF OZONE EXPOSURE EXPERIMENTS OF ANNUAL MEDITERRANEAN PASTURES FOR SETTING OZONE CRITICAL LEVELS

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Ozone (O_3) exposure- and flux-based critical levels (CLe) have been established in the Mapping Manual of the Convention on Long Range Transboundary Air Pollution (CLRTAP, 2010) for different (Semi-)natural vegetation categories. However, current O_3 CLe only cover a small fraction of the wide range of plant communities found across Europe and the information available includes few representative species of each plant community (CLRTAP, 2010). Further efforts must be done to extend the scientific information in terms of species and communities upon which O_3 CLe are based in order to obtaining reliable risk assessments of O_3 effects on European (Semi-)natural vegetation.

Data of O_3 effects in annual pastures have been reviewed in the past for setting AOT40-based CLe to be applied where this type of pastures are found (CLRTAP, 2010). However, this information appears to be dated after several publications in recent years on O_3 effects on annual Mediterranean pastures studying species representative of dehesa pastures (Sanz et al., 2005, 2007, 2011, 2013, 2014). Dehesas are one of the most characteristic landscapes of the central and South-Western Iberian Peninsula, typically composed in the understory by O_3 sensitive annual pastures which ecophysiology is controlled by soil moisture availability. Their value is associated with its high biodiversity, constituting also a food resource for extensive cattle as well as wild herbivorous species. Dehesa annual pasture species are also present in other Mediterranean pastures and forming the understory of sclerophyllous Mediterranean forests. In the Mapping Manual framework, Mediterranean annual pastures are considered within the category "Grasslands of high conservation value" with a specific AOT40-based CLe but it is recognized that no information was available to derive a POD-based CLe.

In this background document we present a revision of open-top chamber (OTC) studies on O_3 effects in annual dehesa pasture species. Exposure- and dose-response relationships are derived from the analysis of the experiments included in this revision. Updates and changes in the Mapping Manual on AOT40- and POD-based O_3 CLe for annual Mediterranean pastures are proposed based on the results of the revision.

OZONE EFFORT, A FIVE-YEAR STUDY ON OZONE EXPOSURE, FLUX AND EFFECTS ON VEGETATION IN TRENTINO (NORTHERN ITALY): A SYNTHESIS

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The project Ozone EFFORT (Ozone EFfects on FORests in Trentino) was carried out in the province of Trento, northern Italy (6207 km^2) over the 2007-2011 period to provide explicit answers to three main questions: (i) is there a potential risk placed by ozone to vegetation? (ii) Are there specific ozone symptoms on plants, and are they related to ozone levels? (iii) Are there ozone-related effects on forest health and growth? Different methods and techniques (field sample survey for ozone levels, injury, and chlorophyll-related measurements; modeling for spatialization, ozone flux, and effect assessment) and vegetation targets (*ad hoc* introduced and spontaneous bioindicators, forest trees) were adopted.

As for question (i), mapped ozone exposure (AOT40) after measurements by passive sampling and conventional monitors revealed exceedance of risk thresholds (both EU Directive 50/2008 and UNECE) for >90% of the investigated area (Gottardini *et al.*, 2010, *Atmos. Environ*., 44, 147-152; Ferretti *et al.*, 2012, *J. Environ. Monit*., 14, 2238–2244; Cristofori *et al.*, 2014, *Ann. For. Sci.*, DOI 10.1007/s13595-014-0440-y).

As for question (ii), although ozone levels were significantly related to foliar symptoms and height increment of introduced *Nicotiana tabacum* L. Bel-W3 plants, other factors (site, time, air temperature, relative humidity) resulted equally or even more important (Cristofolini *et al.*, 2011, *Ecol. Ind.*, 11, 1065–1073). Foliar symptoms on the spontaneous, ozone-sensitive *Viburnum lantana* L. were significantly (but not proportionally) related to ozone exposure both in time (Gottardini *et al.*, 2010, *J. Environ. Monit.*, 12, 2237–2243) and space (Gottardini *et al.*, 2014, *Sci. Tot. Environ.*, 493, 954–960). In the former case, results were corroborated by chlorophyll content and stress signals (chlorophyll *a* fluorescence transient analysis) (Gottardini *et al.*, 2014, *Ecol. Ind.*, 39, 65–74).

Finally [question (iii)], statistical analyses on forest health (in terms of defoliation) and growth (in terms of basal area increment) measured at 15 ICP Forests Level I plots revealed scarce relationship with ozone exposure. Instead, damage due to biotic and abiotic causes and foliar nutrition were consistently identified as the main drivers. Ozone flux estimated for one intensive *Picea abies* (L.) Karst. site over the 1996-2009 period exceeds frequently and largely the recommended POD_1 8 mmol m^{-2} (CLRTAP, 2014). Yet, no relationship was found with health and growth, nor foliar symptoms were reported (Ferretti *et al.*, in prep.).

In conclusion, the potential risk for vegetation in terms of ozone exposure and flux is very high in Trentino. Evidence of effects, however, are limited, and decreases when moving from specific bioindicator plants to forest trees, and from foliar symptoms to forest health and growth.

OVERVIEW OF THE ACHIEVEMENTS OF THE ICP VEGETATION IN 2014 AND FUTURE WORKPLAN (2015 – 2017)

Harmens, H.[1], Mills, G.[1], Hayes, F.[1], Sharps, K.[1],
and the participants of the ICP Vegetation

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The ICP Vegetation is an international programme that reports on the effects of air pollutants on natural vegetation and crops [1]. It reports to the Working Group on Effects (WGE) of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). In particular, the 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. The ICP Vegetation also studies the impacts of pollutant mixtures (e.g. ozone and nitrogen), impacts on ecosystem services and biodiversity, and interactions between air pollutants and climate change.

At the 28th Task Force Meeting we will report on the achievements of the ICP Vegetation in 2014 [1], including:

- Air pollution deposition to, and impacts on vegetation, in EECCA/SEE countries and South-East Asia [2];
- Update of Chapter 3 of the Modelling and Mapping Manual [3];
- Supporting evidence for ozone impacts on vegetation, including bean biomonitoring and smart phone App for recording incidences of ozone injury;
- Preparations and progress with the European moss survey 2015/2016;
- Contributions to common workplan items of the WGE.

We will also discuss the future workplan (2015 – 2017), such as progress made with items to be reported to the LRTAP Convention in 2015:

- Implications of rising background ozone for vegetation in Europe;
- Interacting effects of co-occurring pollutants (ozone and nitrogen) and climatic stresses on vegetation.

And other deliverables for the immediate future:

- Update report on field-based evidence of ozone impacts on vegetation (2016);
- Report on ozone impacts on biodiversity (2016);
- Ozone critical levels workshop (autumn of 2016);
- Revised ozone risk assessments methods and further revision of Chapter 3 of the Modelling and Mapping Manual (2017);
- Report on the outcome of the European moss survey 2015/2016 (2017/18).

Acknowledgement
We thank the UK Department for Environment, Food and Rural Affairs (Defra) for funding the ICP Vegetation Programme Coordination Centre. Further financial support was provided by the UNECE and the UK Natural Environment Research Council (NERC).

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[2 http://icpvegetation.ceh.ac.uk/publications/documents/CEHOzoneReport2014_webhighres.pdf
[3] http://icpvegetation.ceh.ac.uk/publications/documents/Updatedchapter3_formattedSep2014.pdf

COMBINED EFFECTS OF OZONE AND NITROGEN ON ECOSYSTEM SERVICES: EXPERIMENTAL RESULTS AND MODELLED FUTURE IMPACTS

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Combined effects of ozone and nitrogen pollution on *Betula pendula* were investigated in solardomes at CEH Bangor using a factorial combination of seven ozone treatments and four nitrogen regimes. Although N increased biomass production, and therefore carbon sequestration, this effect was reduced with increasing ozone. In addition, N content of senescing leaves was increased with increasing ozone exposure, implying decreased resorption of nitrogen and alterations in litter quality. A model of soil and vegetation responses to atmospheric nitrogen pollution and other drivers, MADOC, was extended to simulate effects of ozone on plant productivity and litter quality based on these and other published data. The revised model was applied to several experimental and long-term monitoring forest sites from across Europe, producing reasonably accurate predictions of NPP, soil water quality and soil total C/N. The model was then used to predict the impact of potential future ozone and nitrogen scenarios (up to 2100) at the sites, to show ecosystem relevant effects including carbon sequestration, soil water pH and DOC. The predicted impacts were for elevated ozone to cause a reduction in NPP, soil carbon and DOC in soil water, but for an increase in the pH of soil water. However, elevated N deposition caused an increase in NPP, soil carbon and soil water DOC and DON.

Stomatal conductance modelling for assessing ozone impacts on deciduous trees

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Ozone enters leaves via stomata and causes a damage to trees. Modeling of stomatal conductance is considered as an essential factor to assess ozone impacts. In this presentation, recent developments for the modeling of stomatal conductance are summarized: 1) stomatal conductance parameters for the Jarvis-type model of deciduous trees throughout the world. A literature survey allowed to investigate the key components of stomatal response to environmental factors (i.e., light intensity, temperature, air humidity and soil moisture) according to the Jarvis-type model in forest plant functional types, and 2) an optimization model of stomata including ozone effects based on free-air ozone exposure experiment on Siebold's beech (*Fagus crenata*), the representative deciduous tree species in cool-temperate forests in Japan. To discuss the effect of ozone on stomatal conductance, we applied the optimal stomatal model including water, CO_2 and ozone flux using gas exchange data of Siebold's beech. An analytical model was proposed based on the optimization model of stomatal conductance for maximizing carbon gain while minimizing concurrent accompanying water loss and ozone influx.

Regarding 1), we found no significant difference across forest types' g_{max} (maximum stomatal conductance), which is the most important parameter in predicting stomatal conductance in the Jarvis-type model. The optimal temperature of stomatal conductance and stomatal response to predawn water potential changed according to the growth conditions.

Regarding 2), the optimal stomatal model explained ozone-induced stomatal closure in early summer. This suggests that ozone-induced stomatal closure may reduce ozone influx, and allow maximum photosynthetic capacity to be reached. However, in late summer and autumn, the model did not explain the effects of ozone on stomatal conductance. Also an increase of y-intercept of the photosynthesis-stomatal conductance relationship (g_{min}, minimum conductance) was found. This reflects the loss of closing response of stomata by ozone (i.e., stomatal sluggishness) such as under low light conditions.

OZONE IMPACTS ON VEGETATION IN NORTHERN EUROPE – CLIMATE CHANGE IMPACTS ON THE OZONE SENSITIVITY PERIOD AND THE CHANGE IN OZONE CONCENTRATIONS WITH HEIGHT ABOVE GROUND

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In recent years ozone impacts on forests have been assessed, today and in the future and in Sweden as well as in Europe (Klingberg et al., 2014, Karlsson et al., 2014). As far as possible the methodology outlined in the Mapping Manual has been used. However, during the work with these assessments, some problems with the present methodology became obvious. The first problem was that the main method to estimate the length of the growing season, i.e. the ozone sensitivity period during the year, was the so called "latitude model". Obviously, this method is not sensitive to climate change. The assessments of ozone impacts on forest growth in Sweden were based on AOT40. When using the default method from the Mapping Manual in order to estimate the ozone concentrations at the top of the canopy in became evident that this method resulted in higher concentrations when compared to empirical data.

These problems will be further presented and possible solutions will be suggested.

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DEVELOPMENT OF SPECIMEN BANKING IN FINLAND AND DISTRIBUTION OF REFERENCE MATERIALS FOR HEAVY METAL MOSS SURVEYS

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The Finnish Forest Research Institute (Metla) established a network of 3009 permanent monitoring sites all over the country in 1985-1986 for forest inventory and monitoring environmental changes in the forests. During the first two years 6 877 moss, lichen and pine bark samples were collected and used for chemical analyses. The monitoring continued every five years and the Paljakka Environmental Specimen Bank (ESB) was established in 1994 to store increasing amount of samples. Soon a large number of forest litter collected since 1958 was placed also to the Paljakka ESB and it became necessary to build an extension part in 1999. Specimen bank lies at an elevation of 345 m, far from anthropogenic emission sources.

Paljakka ESB provides a high quality facility for environmental samples. Total floor area of 770 m^2 includes room for sample pretreatment and nine fireproof storage rooms. At the moment there are over one million samples. Only dried plant material is stored in the Paljakka ESB currently. In Finland the Finnish Environment Institute (SYKE) stocks animal specimen material mostly under freezing temperatures.

Stored samples originate from several national and international projects like UNECE ICP Vegetation and ICP Forests. On the European scale samples represent the background area and are very sensitive for environmental changes. In 2003-2006 Ministry of Agriculture and Forestry and Ministry of Education together with Metla launched the research and development project for the storage and use of environmental samples in Finland. Forthcoming aims, collaboration and future prospects for Paljakka ESB will be presented in the conference.

Moss reference materials collected and prepared in Finland have been used since 1995 moss survey for quality assurance in participating laboratories. The reference materials are stored in the Paljakka ESB. The use and distribution of these materials in the 2015 survey will be discussed in the conference.

QUANTIFY THE IMPACT OF TROPOSPHERIC OZONE ON CROPS PRODUCTIVITY USING JULES-CROP

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Tropospheric ozone (O_3) is the third most important anthropogenic Greenhouse Gas and is detrimental to plant productivity. Ozone already causes significant crop production losses (5 Billion $ per year in US, similar in EU) with concentrations increasing in south Asia and South East Asia, which have significant agricultural areas and large, growing populations. The aim of this research is to quantify the impacts of present-day and future tropospheric O_3 on crop production at the regional scale until 2050, using the Joint UK Land Environment Simulator adapted to include the major global crop types (JULES-crop). JULES forms the land surface component of the latest generation Earth System Model (ESM) at the Hadley Centre. JULES-crop will be extensively evaluated against the Soybean Free-Air-Concentration-Enrichment (SoyFACE) experiment to include and develop O_3 impacts on crops.
JULES-crop will be applied in a coupled ESM to quantify feedbacks between coupled climate-crops and atmospheric chemistry.

JULES-crop parameters such as top leaf nitrogen concentration and nitrogen ratio in leaf and root are modified to calibrate the Vc max with SoyFACE observation. Prescribing JULES with monthly average ozone input reduce the ozone damage effect than using daily input. Soybean shows a low ozone sensitivity according to the value stated in Sitch et al., (2007). Initial result shows that soybean yield decrease as ozone (AOT40) increase in a linear function. Interactions of CO_2 fertilisation and O_3 damage on crops will be studied and apply to regional scale simulation in four Representative Concentrations Pathways (RCPs).

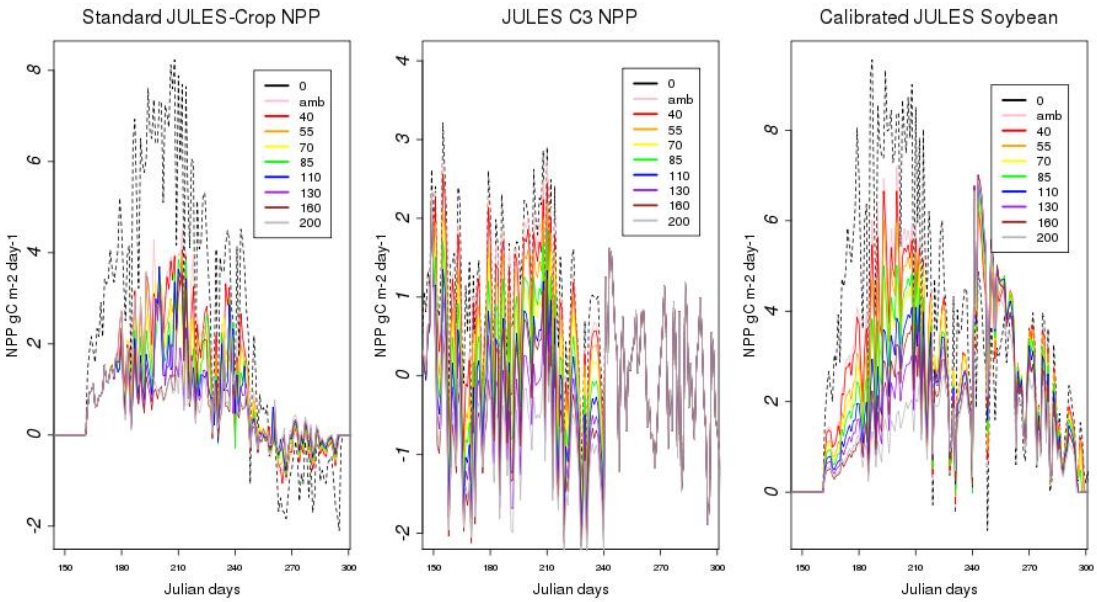

Figure 1. Simulations of the Net Primary Productivity of soybean of different target ozone using: (from left to right) standard JULES-Crop, standard JULES with C3 grass instead of soybean, calibrated and tuned JULES-Crop parameters

GREEN INFRASTRUCTURES AND ECOSYSTEM SERVICES: DIFFERENT VEGETATION TYPES AND AIR QUALITY IMPROVEMENT IN THE METROPOLITAN AREA OF ROME.

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Many European cities have a long history, that has impacted not only on development of the cities themselves, but also on the characteristics of their green spaces. The transformations of the late nineteenth century were characterized by expansion of the urban fabric, that led to the building of a large part of the surrounding area, resulting in changes in the microclimate, in the quality of air, in the circulation of water and, last but not least, in alienation of man from nature. The concept of Ecosystem Services (ES) was defined by Daily (1997) as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life". Until now, the study of Ecosystem Services has not given much attention to plant-atmosphere relationships. In this context, the role of Green Infrastructures (GI) to reduce the main air pollutants levels should be an important aspect to be considered, also in terms of their economic evaluation.

This work investigates the regulating Ecosystem Services of particulate matter and tropospheric ozone removal, provided by urban and periurban forests in the metropolitan area of Rome. In particular the objective is to evaluate the differences of air pollution removing capacity between evergreen and deciduous forests, in relation to their maximum seasonal Leaf Area Index, and to analyze this ES in relation to air pollutant concentration and different vegetation types. The observed stabilization effect on the pollution removal function, being due to the morpho-functional characteristics of the considered vegetation types, highlights the need to preserve biodiversity, particularly in urban areas and in the current context of climate change. Green Infrastructures, natural or semi-natural green spaces and corridors, and their biodiversity, represent an important resource to be preserved, increased and sustained, in aiming to ameliorate the air quality of the whole environment, especially in dense populated metropolitan areas. Our results confirm the crucial role of urban and periurban forest in supporting significant Ecosystem Services as air quality improvement, also highlighting the importance of GI of sustain and enhance benefits provided by trees.

YIELD COMPONENTS OF WINTER WHEAT AS AFFECTED BY LEAF RUST DISEASE UNDER ELEVATED CO_2 AND/OR O_3

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Knowledge of the effects of climate change and leaf rust disease (caused by *Puccinia recondita*) on winter wheat is important for maintaining grain yield. Studies on the components of both disease and yield under elevated levels of CO_2 and/or O_3 are needed. Carbon dioxide and O_3 are not usually tested in experiments that include plant diseases, although these gases are expected to have effects on plant-pathogen interactions.

In this study, four winter wheat genotypes ('Coker9553', 'NC-Neuse', 'Jamestown' and 'NuEast') known to differ in their response to leaf rust (susceptible, moderately susceptible, moderately resistant and resistant, respectively) were grown until maturity under one of four combinations of CO_2 (400, 570 ppm) and O_3 (10, 50 ppb) in custom-built chambers with temperature and relative humidity control (Flowers et al., 2007). Plants were inoculated with leaf rust urediniospores spores at Zadoks growth stage of 39-40.

Disease severity was significantly increased by elevated ozone (O_3) in Coker9553 and NC-Neuse. The combination of the two gasses (CO_2+O_3) increased disease severity only in Coker9553. Elevated CO_2 had no significant effect on disease severity on all genotypes. Pustule size was increased in Coker9553 by bothO_3 and CO_2+O_3. Gas treatment had no significant effect on pustule size in NC-Neuse and Jamestown. Only elevated O_3 significantly accelerated the pathogen sporulation on Coker9553. In contrast, both CO_2 and CO_2+O_3 significantly delayed the pathogen sporulation in NC-Neuse.

Rust infection significantly reduced grain yield under charcoal filtered (CF) and CO_2+O_3 and had no effect under CO_2 and O_3 alone. Non-inoculated plants grown under CO_2 or CO_2+O_3 had significantly higher yield than non-inoculated plants grown under O_3. For rust-inoculated plants, CO_2 significantly increased yield. There was no interaction between rust and gases on single kernel weight within each genotype. Rust significantly decreased the total number of kernels per plant, compared to non-inoculated plants.

Rust significantly reduced the total vegetative dry weight of all genotypes under all gas treatments. CO_2+O_3 and CO_2 alone increased biomass of all genotypes overO_3 treated plants. For non-inoculated plants, CO_2+O_3 had significantly increased tillering over CF-grown plants. Rust infection decreased the tillering of plants grown only under CO_2+O_3. Tiller weight was significantly reduced in all genotypes by rust infection but not by gas treatment. Plants height was increased by CO_2+O_3, but was unaffected by rust.

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RELEVANCE OF CANOPY DRIP FOR THE ACCUMULATION OF NITROGEN IN MOSSES ACROSS EUROPE

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Background Reactive nitrogen can have various adverse effects on the environment. High and long-term inputs of nitrogen (N) from the air (deposition) constitute an unlimited risk for biodiversity and functionality of (semi-) natural ecosystems, particularly for habitats with low soil pH buffering capacity. Due to filtering effects of their canopy, forest ecosystems are particularly prone to high atmospheric N inputs. Our study analyses the relevance of canopy drip on the accumulation of N in mosses used as biomonitors for atmospheric deposition in seven European countries.

Methods Therefore, the moss samples were collected and analysed according to the guidelines of the European moss survey. Additionally for comparison canopy drip effects were analysed for ammonium and nitrate measured with technical deposition samplers. The statistical evaluation included descriptive statistical analyses taking canopy drip effects into account. Moreover, the ratio between the total N concentrations in moss specimen sampled at sites located in open land and at sites influenced by canopy drip was computed. This ratio was used to calculate spatial estimates for sites where moss was collected either within or outside of canopies. Furthermore, potentially influencing environmental predictors (e.g. precipitation, elevation, distance to sea, population density, and modelled atmospheric N deposition and land use indices) were integrated into multivariate analyses in order to uncover relationships between the total N concentration in moss as well as ammonium and nitrate measured in deposition samplers.

Results The findings for the different European countries are quantitatively described. Therefore, the sampling locations were grouped according to the influence of canopy drip. For areas influenced by canopy drip, an increasing amount of N concentration could be substantiated provided, both, by the analysed mosses and the technical deposition samplers. This was also confirmed by the results of the multivariate analyses identifying the sampling site category (site with/without canopy drip) being the factor most associated with the N concentration in moss.

Conclusion Up to now, there are only few peer reviewed studies that analyse the canopy drip effect on the accumulation of N in mosses. Therefore, our study aimed at investigating possible canopy drip effects. The results support the assumption that forest ecosystems show higher N concentrations in moss due to filtering of dry deposition within the canopy compared to respective concentrations outside of forests. This is in contrast to open land deposition that mainly covers wet and occult (fog) deposition. Spatial variances should be considered in future monitoring networks.

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Overview of Progress for the EU FP7 ECLAIRE[1] project

Gina Mills[2], Mark Sutton, CEH, UK and many colleagues from the ECLAIRE project

[1]Effects of climate change on air pollution impacts and response strategies for European ecosystems. [2] gmi@ceh.ac.uk

Running for just over three years, the EU FP7 project ECLAIRE brings together experts from many specialisms to develop new ways of modelling the risks posed to European ecosystems from the combined effects of air pollution and climate change. This unique combination of scientists covering effects at the leaf scale through to modelling impacts on European ecosystem services and climate, and including experts on ozone, nitrogen, aerosols and climate change met recently in Zagreb, Croatia to discuss progress at the half-way stage of the project. This presentation will provide a brief overview of progress with the project, with particular emphasis on aspects of relevance to ICP Vegetation and policy makers at the LRTAP Convention.

The project is split into five main scientific components: (1) Emissions and Exchange processes; (2) Emissions and exchanges at local to EU and global scales; (3) Ecological response processes and thresholds; (4) Ecological responses at regional and European scales; and (5) Integrated risk assessment and policy tools. ICP Vegetation participants have greatest involvement in component 3, including analysis of data mined from the published literature to derive dose-response relationships for physiological and growth responses, experimental exposure of crops, grassland and tree species to combinations of ozone and nitrogen pollutants, investigations of leaf-scale processes and model development including photosynthesis-based ozone uptake and growth models, MADOC for species changes and JULES (a land-surface climate model). Results from ECLAIRE are included in other presentations at the Task Force Meeting, including: Session 3a (Gonzalez-Fernandez et al., Büker et al.), Session 5a (Büker et al., Gerosa et al.); Session 6a (Fares et al.); Session 7a: (Hayes et al., Finco et al.). As well as providing an overview of ECLAIRE, this paper will also include results from an analysis of published data on ozone and N interactions.

COMPARING RESULTS OF MODELLING AND MAPPING SPATIO-TEMPORAL TRENDS OF CADMIUM, MERCURY AND LEAD ACCUMULATION IN MOSS AND NATURAL SURFACE SOIL THROUGHOUT NORWAY DERIVED BY DIFFERENT STATISTICAL METHODS

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Objective. Based on both moss specimen collected throughout Norway in 1990, 1995, 2000, 2005 and 2010 and on natural surface soil sampled in 1995 and 2005, this study investigates the trend of spatial patterns and statistical relations between the concentration of heavy metals (HM) in moss and natural surface soil and 10 potential influencing factors.

Methods. Next to descriptive and correlation statistics, spatial patterns of concentrations of Cd, Hg and Pb in moss (1990-2010 every 5 years) and natural surface soil (1995, 2005) were analysed and mapped by use of Variogram Analysis and Ordinary Kriging. Additionally, *Generalized Linear Models (GLM)* and afore mentioned geostatistical methods were combined including a set of 10 potential predictors such as elevation, precipitation, density of different land uses, population density, or soil properties. This *Regression Kriging (RK) approach yielded* RK-maps of HM concentrations in moss and natural surface soil which were then used to investigate to what extent HM accumulations are correlated. The maps derived by Ordinary Kriging *(OK)* and that based on *RK* were compared.

Results. From a set of ten potential predictor variables the modelled atmospheric deposition revealed the highest correlation with HM concentrations in moss and natural surface soil. The density of various land uses in a 5 km radius showed significant correlations with Pb and Cd concentration in moss and Hg concentration in natural surface soil. Elevation also appeared as a relevant factor for accumulation of Pb and Hg in moss and Cd in natural surface soil. Precipitation was found to be a significant predictor for Cd in moss and Hg in natural surface soil. The integrated use of multivariate *GLM* and *RK* enables calculating HM maps at a spatial resolution of 5 km by 5 km. The spatial patterns of Cd and Pb concentrations in moss and natural surface soil in 1995 and 2005 were similar. HM concentrations in moss and natural surface soil were correlated significantly with high coefficients for Pb, medium for Cd and moderate for Hg. From 1995 up to 2010 the modelled moss and natural surface soil estimates indicated a decrease of Pb concentration in both moss and natural surface soil. With respect to the moss data the decrease of HM accumulation was more pronounced. By contrast, the modelled Cd and Hg concentrations did not exhibit any significant temporal trend. The comparison of *OK* maps and *RK*-Maps proved the latter to be more differentiated and less smoothed.

Conclusions. It has been shown that data on HM concentrations in natural surface soil could complement moss monitoring but should not replace it since the HM concentration in moss reliably traces the spatial pattern of respective atmospheric deposition. *GLMs* and *RK* enlarge the methodology for estimating spatial patterns and temporal trends of HM concentration in moss and natural surface soil and enable higher differentiation.

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REACTIVE OXYGEN SPECIES AND ANTIOXIDANT MACHINERY IN *LIRIODENDRON TULIPIFERA* PLANTS EXPOSED TO OZONE

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Trees are essential in the urban environment not only because of their aesthetic and social values, but also for their effects on air quality. Data of the present work show some of the integrated mechanisms that may confer sensitivity/tolerance in *Liriodendron tulipifera* (known as the tulip tree) saplings exposed to ozone (O_3) (120 ppb, 5 h day^{-1} for 45 consecutive days) in order to improve the management of green spaces responding to oxidative stress. At the end of fumigation, visible injury due to O_3 was observed: symptoms were minute (Ø 1-2 mm) roundish dark-blackish necrosis, mainly located in the interveinal areas of recently fully expanded leaves. The injured leaf area was about 40% of the total surface. Reactive oxygen species levels, membrane injury, enzymes/metabolites linked to ascorbate-glutathione (AsA-GSH) cycle and to the synthesis of phenylpropanoids show modifications caused by O_3 in terms of: (*i*) increase in the superoxide radical production (+41%, in comparison to air filtered controls); (*ii*) reduction in accumulation of hydrogen peroxide (-55%) and of the enzymes involved in its metabolism [as confirmed by the decrease in superoxide dismutase and catalase activities (-33 and -82%, respectively)]; (*iii*) increase of antioxidant capacity [as documented by the improved 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) scavenging activity]; (*iv*) alteration in the solute reactions of the membrane cells [as showed by the production of thiobarbituric acid reactive substances (+34%)]; (*v*) inhibition of enzymes linked to AsA-GSH cycle [as confirmed by the decrease of ascorbate peroxidase (-48%), monodehydroascorbate, dehydroascorbate and glutathione reductase activities (-44, -56 and -80%, respectively)]; (*vi*) changes of the normal reduced state of cells [as evidenced by the decrease in the reduced ascorbate/dehydroascorbate and in the reduced/oxidized glutathione ratios (-37 and -60%, respectively)]; (*vii*) activation of enzymes involved in phenolic metabolism [as highlighted by the increase of phenylalanine ammonia-lyase and cinnamyl alcohol dehydrogenase activities (+75 and +67%, respectively)]; (*viii*) development of cellular barriers with a higher degree of polymerization of monolignols [as indicated by the increase of lignin (+47%)] and (*ix*) accumulation of phenolic and anthocyanin compounds (+68 and +43%, respectively). These results indicate that O_3 exposure modifies reactive oxygen species metabolism rates, but the enzymatic and non-enzymatic antioxidant systems (that work in co-operation) could not provide a defence against free radicals, not preventing the oxidative damage. In conclusion, under these circumstances, *L. tulipifera* should be regarded as sensitive to this pollutant.

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EMISSIONS FROM ADJACENT METAL INDUSTRIES STUDIED BY "MOSS BAGS"

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Deposition of heavy metals all over Norway has been regularly investigated since 1977 by analysis of the naturally growing moss *Hylocomium splendens*. More recently this approach has also been used to study metal deposition at sites where major industries are located, such as the metal industry at Mo i Rana. In this case there was no naturally growing moss inside the industry area and sampling was restricted to neighbouring sites.

The use of "moss-bags" opens a possibility to extend moss biomonitoring to areas and territories where the moss does not grow naturally, such as inside the Mo i Rana Industrial Park. Moss samples from a background area were placed in hairnets, cleaned with 0.2 M HCl and dried, and then hung in trees for a two months period at around 30 sites within the industrial area. The exposed moss samples were decomposed with concentrated HNO_3 in an UltraClave unit and analyzed for 46 elements by ICP-MS. The obtained data were subjected to factor analysis for possible source apportionment.

The deployment of moss bags was aiming at distinguishing between emissions from three main industrial sources: Celsa Armeringsstål AS receiving scrap metals for re-melting, FESIL Rana Metall AS producing ferrosilicon, and Glencore Manganese Norway AS producing ferromanganese alloys. In addition some moss-bags were placed at positions to evaluate contributions from other potential sources inside the park such as waste disposal sites, scrap yard, and mass transportation.

The metals showing the highest ratios relative to unexposed "moss-bags" were Cd, Cr, Mn, Mo, Pb, and W, reaching values of 200 or more. In addition the "priority metals" Zn, Hg and As showed relatively high values. These elements are essentially the same that had shown high values in previous moss surveys at Mo i Rana. The values for Mn were highest near Glencore, as expected considering the production. Al, Ca, Cr, Fe, Hg, Mg, Mo, and W showed peak values around Celsa. Concentrations of As were highest in the area nearby FESIL and Glencore, probably with FESIL as the main contributor. Cd, Pb and Zn showed the highest levels next to the Celsa scrap yard, which is also affected by mass transportation. Pb and Zn also show high concentrations nearby Celsa, whereas Cd shows no clear pattern. The Celsa emissions depend on the quality of the scrap metal received.

Even though the geographical distribution of some metals monitored in this study showed good accordance with emissions reported by the three plants, it proved difficult to distinguish contributions from sources located close to each other. Still this moss bag study improved considerably the understanding of contributions from different sources compared to previous studies of naturally growing moss sampled outside the industrial area

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MONITORING OF HEAVY METALS IN AMBIENT AIR FROM GARHWAL HILLS (INDIA) USING MOSS *Hypnum cupressiforme* HEDW.

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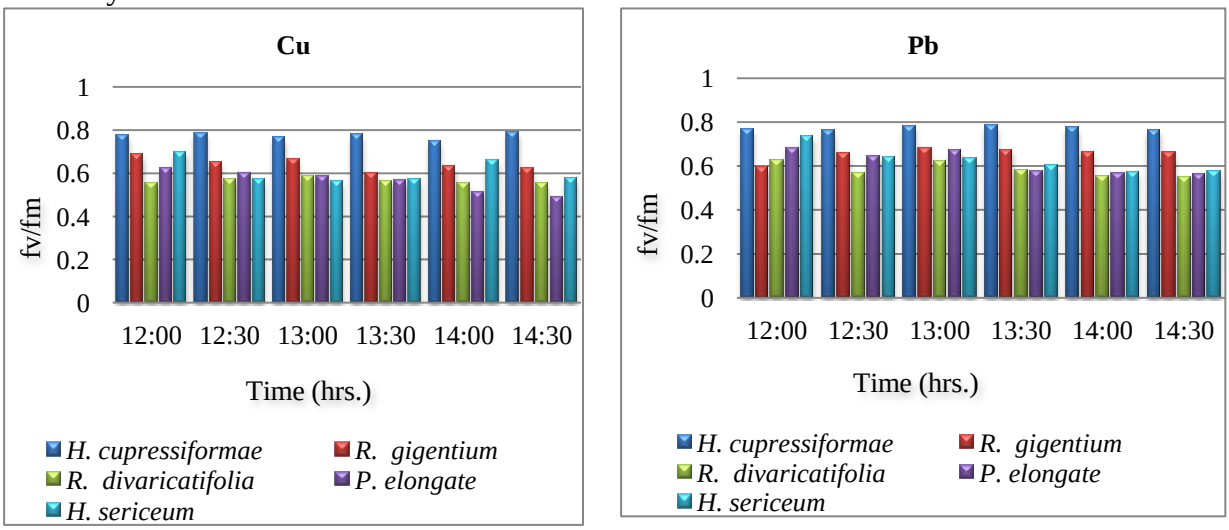
Heavy metals were pollutants of great concern as they are non-degradable and toxic. To assess the metal deposition in ambient air, biomonitoring technique using mosses is widely used because approach is simple and inexpensive as compared with the rather arduous methods of analysis. A general advantage of the biomonitoring approach is related primarily to the permanent and common occurrence of the organism in the field even in remote areas, the ease of sampling and no need of any expensive technical equipment. Moss species may vary in accumulation behaviors, may confuse or influence the results, therefore they have to be validated for metal tolerance by quickly *non- invasive* approach before inducting in biomonitoring.

Study was conducted to know the seasonal trend of metals, deposition rates and pathways. Five commonly grown moss i.e. *Rhodobryum giganteum* (Schwaegr) Par., *Rhynchostegiella divaricatifolia* (Renauld & Cardot) Broth., *Pohlia elongate* Hedw., *Hypnum cupressiforme* Hedw. and *Homalothecium sericeum* (Hedw.) Schimp. were collected from monitoring sites and validated for their tolerance against different metals (Zn, Cu, Cd and Pb) by measuring their chlorophyll fluorescence signals. Amongst validated species moss *Hypnum cupressiforme* Hedw. was inducted for monitoring program. The levels of Zn, Cu, Cd and Pb were determined in moss *Hypnum cupressiforme* transplanted at Mussorie, Dhanaulti, Chamba and New Tehri of Garhwal regions of India by atomic absorption spectrophotometery.High lead was measured in moss harvested from locations in proximity of higher traffic density areas of Mussorie, which could be attributed to enhanced tourism during summer. In rural areas high Zn (54.83 µg/gm) and Cu (85.07 µg/gm) could not be ruled out from fertilizers. Positive significant correlations were obtained between Pb-Zn and Zn-Cu that suggest a non-common source of origin. Elemental concentration in transplanted moss was in order Zn>Pb~Cu>Cd in summer while same was in order of Zn>Cu>Pb>Cd in winter and in rain Zn>Cu>Pb>Cd that reflects atmospheric elemental load. For quality assurance calibration was also done.The urban and rural pattern of the correlation between atmospheric deposition in moss clearly differs for Zn and Pb, however seasonal pattern was nearly identical for urban and rural metal data.

Key Words: Biomonotoring, Heavy Metals, Mosses, *Hypnum cupressiforme*, Garhwal Himalaya.



Effect of Cu and Pb on different moss

HEAVY METALS AND NITROGEN CONCENTRATIONS IN MOSS COLLECTED ACROSS EUROPE 2010 / 2011: STATISTICAL ANALYSES COVERING FOUR SPATIAL SCALES

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Background As in previous European Moss Surveys (EMS) 1990, 1995, 2000, and 2005, moss samples were collected 2010 / 2011 in 25 countries at about 4500 sites and the elemental concentrations were determined in the last two to three years' growth segments according to a standardised protocol. Quality was assured by using moss reference material. Where necessary, correction factors were applied to outliers, or severe outliers were excluded from further data processing. The reported data were checked for anomalies and the format standardised. This data was handed over to the Chair of Landscape Ecology for statistical analyses going beyond the survey report **[1]** according to a design agreed upon on the occasion of the 27th Task Force Meeting.

Methods The data were integrated into a Geographic Information System (GIS). The statistical design capture, amongst others, methods already applied to the 2005 survey data and to those from the Norwegian survey 2010 and published by the participants **[2, 3]**. The analyses regard several chemical elements (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sb, V, Zn, S, N), four spatial scales (Europe as a whole of participating countries, single participating countries, natural landscapes across Europe and within single European countries) and methods (descriptive statistics, geostatistics and GIS-mapping, multivariate statistics).

Results The first steps of statistical analysis could be completed. Amongst others, it revealed a sufficient number of moss sampling sides across Europe as a whole, indicated by the Minimum Sample Size (MSS), regarding all investigated elements. Whereas this holds not totally true concerning lower scaled spatial units (e.g. national scale, natural land units). Concidering the respective mean values of element concentrations in mosses, the analysis carried out that about the half of the countires exceeded the measured European mean value for Cd (48% of the countries with measurements) and N (53%) and still more than one third of the countries for Hg (42%) and Pb (41%). However, not all deviations proved to be statistical significant ($\alpha \leq 0.05$).

Outlook As done with the results of respective statistical analyses computed by use of the European 2005 survey data **[3]**, results of the statistical analyses of the EMS 2010 will be published in common papers.

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ICP FORESTS: THE PROGRAMME AND ITS CURRENT OBJECTIVES

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The International Co-operative Programme (ICP) Forests is one of the programmes operating under the CLRTAP within the context of the Working Group on Effects. It is dedicated to the assessment of air pollution effects on forest ecosystems. It operates on two intensities: The Level I monitoring addresses large-scale effects on an area-representative 16 by 16 km raster (Lorenz 1995) while the intensive (Level II) monitoring consists of case studies in major forest ecosystem types (de Vries et al. 2003). All measurements are to be performed according to an extensive Manual (ICP Forests 2010).

While sulphur emissions have been drastically reduced in Europe over the last decades, emissions of nitrogen compounds have not. Therefore, N inputs into forest ecosystems are still of high relevance. Reactive N being historically in short supply, its addition at first had positive effects on tree performance (e.g. growth). With its saturation in forest ecosystems, however, more and more adverse effects may emerge at different compartments of these systems. Two sensitively reacting groups of organisms are epiphytic lichens (Giordani et al. 2014) and mycorrhiza fungi (Suz et al 2014). The responses of trees and other vascular plants seem to be more difficult to detect, however, first hints have been found (Dirnböck et al 2014). At the ecosystem level the detection of effects using simple indicators seem to be also less obvious. Additionally, N compounds are among the most import precursors substances of ozone formation in the troposphere.

Activities within ICP Forests currently concentrate on knowledge gaps in regard of N inputs and ozone impacts in forest ecosystems. While there is a long co-operation concerning tropospheric ozone in forest ecosystems between ICP Vegetation and ICP Forests, there seem to be developable links between the two programmes with respect to the detection of adverse nitrogen effects, e.g. by studying bryophyte element contents (Harmens et al. 2011) and large-scale distributions of moss species.

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ICP VEGETATION OZONE SMART-PHONE APP: UPDATE ON 2014 PILOT STUDY

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At the ICP Vegetation Programme Coordination Centre, we have developed a smart phone App (and web-based facility) for recording incidences of ozone injury in the field. We aim to add to the data gathered for the 2007 Evidence Report (Hayes et al., 2007) to create an extensive spatial dataset on incidences of ozone injury under ambient air conditions around the world. Using the App, photographs of ozone injury can be uploaded in the field, with the coordinates of the location recorded automatically using GPS. Users are then taken through a series of questions designed to gather information on the experience of the user, ozone injury symptoms and the weather conditions around the time of damage.

The App and web recording form were made available for use by ozone experts in April 2014. Our goals during the 2014 growing season were to trial the App on a variety of models of smart phone and to gather a sample dataset of ozone injury records. The App was found to perform well on different phones, with the help of constructive feedback from App users. The sample dataset of records (n=20) contains information on a variety of species from Europe, USA and Asia. The App will be released to the public in the spring of 2015 and we plan to publicise it extensively over the coming months, for example, via UK plant societies and organisations.

We welcome further feedback from participants who trialled the App during the 2014 pilot season and would like to encourage as many people as possible to download the App and submit records during 2015.

The App (and web recording form) can be accessed using our website:
http://icpvegetation.ceh.ac.uk/record/index

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AN EPIDEMIOLOGICAL ASSESSMENT OF STOMATAL OZONE FLUX-BASED CRITICAL LEVELS FOR SOUTHERN EUROPEAN FORESTS

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Southern forests are at the highest ozone (O_3) risk in Europe where ground-level O_3 is a pressing sanitary problem for ecosystem health. Exposure-based standards for protecting vegetation are not representative of actual field conditions. A biologically-sound stomatal flux-based standard has been proposed, although critical levels for protection still need to be validated**. T**his innovative epidemiological assessment of forest responses to O_3 was carried out in 54 plots in Southeastern France and Northwestern Italy in 2012 and 2013. Three O_3 indices, namely the accumulated exposure AOT40, and the accumulated stomatal flux with and without an hourly threshold of uptake (POD1 and POD0) were compared. Stomatal O_3 fluxes were modelled (DO3SE) and correlated to measured forest-response indicators, i.e. crown defoliation, crown discoloration and visible foliar O_3 injury. Soil water content, a key variable affecting the severity of visible foliar O_3 injury, was included in DO3SE. Based on flux-effect relationships, we derived species-specific exposure-based (CLec) and flux-based critical levels (CLef) for forest protection, by joining data from all plots and years. As AOT40 was better correlated with defoliation than with discoloration and visible injury, we selected defoliation as effect parameter for defining AOT40-based CLec values. As a tree with defoliation above 25% is commonly rated as damaged, CLec was calculated on the basis of a threshold of 25% average stand defoliation. As POD0 was better correlated with visible foliar O_3 injury than with defoliation and discoloration, we selected visible foliar O_3 injury as effect parameter and POD0 as O_3 metric for defining PODY-based CLef values. Unfortunately, a definition of damaged tree/stand based on visible foliar O_3 injury is missing in the literature. We thus based the selection of a visible foliar O_3 injury threshold on a comparison of gas exchange of leaves with a range of visible O_3 injury that was carried out in a 3-year-old O_3-sensitive poplar plantation. CLef was derived from flux-effect functions for 15% of visible foliar O_3 injury (stand level). We obtained CLec of 11.7 ppm.h AOT40 for *P. cembra* (high O_3 sensitivity) and 24 ppm.h for *P. halepensis* (moderate O_3 sensitivity). For broadleaved species, the average CLec was higher than for conifers (23.6 ppm.h AOT40) and similar in the two species with significant correlation between crown defoliation and AOT40, i.e. *Fagus sylvatica* (moderate O_3 sensitivity) and *Fraxinus excelsior* (high O_3 sensitivity). For conifers, CLef of 19 $mmol.m^{-2}$ for *P. cembra* and 24 $mmol.m^{-2}$ for *P. halepensis* were calculated. For broadleaved species, we obtained a CLef of 21 $mmol.m^{-2}$ for *Fagus sylvatica* and of 19 $mmol.m^{-2}$ for *Fraxinus excelsior*. To avoid an underestimation of the real O_3 uptake, we recommend the use of POD0 calculated for hours with a non-null global radiation over the 24-h O_3 accumulation window. We showed that an assessment based on PODY and on real plant symptoms is more appropriated than the concentration-based method. Indeed, POD0 was better correlated with visible foliar O_3 injury than AOT40, whereas AOT40 was better correlated with crown discoloration and defoliation (aspecific indicators).

MOSSES AS BIOMONITORS OF TRACE ELEMENTS IN URBAN AND PERI-URBAN FORESTS: PRELIMINARY RESULTS FOR THE CITY OF LJUBLJANA, SLOVENIA

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Air quality is still one of the major environmental problems of modern society, especially in urbanised areas where the population density is high. The World Health Organization reported that in the year 2012 approximately 40 million people, in 115 European cities, were exposed to air quality exceeding the European Union limit values for at least one of the pollutants. To identify polluted cities and their surroundings, monitoring of air quality is essential. Biomonitoring of trace elements with mosses has a long history of usage. Advantage of this kind of monitoring is that the methodology of data collection is simpler and also the chemical analysis are cheaper; consequently much higher sampling density can be achieved.

The aim of presented study was to explore which parts of the urban and peri-urban forests within the City of Ljubljana show increased deposition of trace elements. To explore this concentrations of trace elements were measured in moss *Hypnum cupressiforme* sampled in urban and peri-urban forests. The City of Ljubljana lies in the central part of Slovenia and covers an area of 275 km^2 with more than 280.000 citizens.

Moss samples were collected in August 2013 at 44 sites within the City. Moss collection locations were divided into two categories, viz. forests within the Ljubljana motorway ring (urban forests) and forests outside the motorway ring (peri-urban and rural forests). Field sampling was performed according to the guidelines of the European moss survey (UN-ECE ICP-Vegetation program). At each sampling site one composite sample was made out of five to seven sub-samples, collected within an area of about 50 x 50 m. Mosses were sampled away from the tree canopy to avoid the canopy drip effect and at least 100 m from main roads, villages and industries to avoid local increased concentrations of the trace elements under study.

Prior to microwave digestion all bryophyte material was dried, cleaned, lyophilized and homogenized in a ball mill. The digests were subjected to analysis by ICP-MS (Agilent 7500ce) for determination of As, Cd, Co, Cr, Cu, Fe, Mo, Ni, Pb, Sb, Ti, V and Zn. For total mercury analysis a direct mercury analyser (DMA-80, Milestone) was used.

In the presentation the preliminary statistical evaluation of the results for the above mentioned elements in urban, peri-urban and rural sampling locations will be presented, together with the spatial distribution of selected elements and discussion related to applicability of biomonitoring of trace elements with mosses in urbanized areas.

MERCURY CONCENTRATIONS IN MOSSES IN CROATIA

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Moss samples from four dominant species (*Hypnum cupressiforme, Pleurozium schreberi, Homalothecium sericeum* and *Brachythecium rutabulum*) were collected during the summer and autumn of 2006 and 2010 from 121 sampling sites evenly distributed over the territory of Croatia. (1)

Samples were totally digested by using microwave digestion system, whilst mercury was analysed by using cold vapour atomic absorption spectrometry (CV-AAS).

Descriptive statistics were done from analyses of mercury in all moss samples. High mercury contents were found in moss samples collected from regions of Podravina and Istria as a result of anthropogenic pollution. (2)

Comparison of median values in 2010 with those found in moss samples in 2006 survey shows slight reduction of mercury air pollution over Croatia.

Key words: Air pollution, Mercury, Moss biomonitoring, CV-AAS, Croatia

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ENVIRONMENTAL POLLUTION WITH HEAVY METALS IN THE REPUBLIC OF MACEDONIA

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Various spectrometric (atomic absorption spectrometry, inductively coupled plasma – atomic emission spectrometry, and inductively coupled plasma – mass spectrometry) and radioanalytical (neutron activation analysis) techniques were applied in environmental pollution studies in the Republic of Macedonia. The results from the surveys of the pollution with heavy metals of soil, waters, sediments, air and food are presented. Air pollution was investigated by the application of moss biomonitoring and dust samples (attic dust and household dust). The pollution with heavy metals in the particular regions was additionally investigated. It was found that the highest pollution is present in the areas with abounded or active mines (Pb, Zn, Ni, Cr, Cu), metallurgical plants (Pb, Zn, Cd, Ni, Cr, Fe, steel) or thermoelectical power plants. High content of some heavy metals were also found in the areas were their contents usually vary gradually across the geochemical landscape and depend on the geochemistry of the underlying lithology. The distributions of such elements reflect natural processes indicated by the elements that are either rarely or never involved in the industrial processes. The obtained data are statistically processed and spatial distribution maps for each specific element are prepared to give a proper interpretation of the obtained results.

ATMOSPHERIC DEPOSITION OF RADIONUCLIDES MONITORED BY MOSS ANALYSIS: FACTS AND FALLACIES

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As the chemical properties of a radionuclide are the same as for corresponding stable isotopes of the same element, mosses can be used as biomonitors of atmospheric deposition of radionuclides, but with the same restrictions as may be applicable for the stable element. Numerous papers are available in the literature suggesting the use of moss species for monitoring radionuclides, such as ^{95}Zr/^{95}Nb and ^{140}Ba/^{140}La [1]; ^{129}I, ^{137}Cs, ^{144}Ce, ^{241}Am [2]; ^{239}Pu, ^{240}Pu [3]; ^{40}K, ^{210}Pb, ^{226}Ra, ^{228}Ra [4], and ^{7}Be [5], *i.e.* a mixture of naturally occurring and artificially produced radionuclides. More recently those papers have been followed by numerous additional publications on the same general topic. Most of the authors were not able to distinguish between fractions of the radionuclide derived from respectively atmospheric deposition and ecosystem transfer following the deposition. Thus the data are not always useful for deposition monitoring.

Monitoring of ^{137}Cs has been frequently discussed in the literature, particularly in connection with major nuclear accidents, and the present talk will concentrate on this important radionuclide, mainly based on own research. Following the Chernobyl accident the ^{137}Cs activity was measured in 470 moss samples collected all over Norway for the 1990 Nordic metal deposition survey. The geographical distribution in the moss samples matched closely the activity distribution measured in surface soils shortly after the Chernobyl fallout had occurred. However, a more detailed investigation of annual increments of moss from the first few years after the accidents demonstrated a substantial transfer of ^{137}Cs from older to younger part of the moss plant. This observation was also made in a corresponding study in Russia [6]. This means that for radionuclides that may be supplied from the growth substrate of the moss and further transported within the plant the measured activity does not necessarily show a true value for the initial deposition. Given that the behaviour of Cs does not vary much among sampling sites, however, the geographical ^{137}Cs distribution long time after an accident may still indicate the original distribution of the fallout from that accident [7].

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ASSESSING SOIL ORGANIC CARBON SEQUESTRATION IN AN ALPINE PASTURE DURING SEVEN YEARS OF INCREASED ATMOSPHERIC OZONE AND NITROGEN DEPOSITION

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In a seven year field experiment effects of weather, time and air pollution effects could be assessed. We linked above- and belowground plant yield, all season net CO_2 exchange measurements and soil sample carbon analysis to evaluate ecosystem C sequestration
Total net ecosystem productivity (NEP) for the seven year period was a gain of c. 370 g C m^{-2} (±20) averaged over treatments. The sequence of weather driven, small scale annual gains and zero balances we found was not consistent with the assumption of a more or less 'steady state' situation in mature ecosystems. In our system soil temperature determined whether the system was a C-sink or –source in a given year. Pollutants had no statistically significant effect on total NEP. Yet, a comparison of the large differences found, suggests a close link with cumulated dry matter yields.

Bulk soil organic C (SOC) concentration in the 0-20cm soil layer (control treatments) rose between 2003 and 2010 from 6.1% (±0.19) to 6.7% (±0.06), equivalent to a +9% change. Meteorological data suggest that this increase in SOC stock is likely productivity related rather than the result of decreased system respiration . Nitrogen causes an N×N interaction that results in reduced C sequestration at high deposition rates. Ozone treatments caused no even remotely significant responses. The antagonistic N effect at high doses indicates that at high N deposition rates respiratory losses grow faster than assimilatory C gains. The C-sink capacity is therefore reduced.

We conclude, that the subalpine grassland ecosystem was a C-sink in the 2003-2010 period. Parameterizations of NEE illustrate the mechanics of this process. But the positive effect of N-deposition on aboveground yield did not translate into similar C-gains in SOM. Instead, in many treatment combinations this 'larger sink effect' was reduced under N- and O3-deposition. It is thus most likely, that the climate dependent aboveground yield is responsible for the increase in SOC during seven years. But weather conditions favoring Reco can result in a negative ecosystem C-balances even in years with high DM yield. NEE measurements suggest, that N-deposition caused extra C-losses via higher microbial respiration after mitigation of N limitation. N-deposition driven yield increases may therefore not be considered as a simple proxy for parallel ecosystem C-pool increases.

Abstracts

Posters

CURRENT KNOWLEDGE ON EDU (ETHYLENE-DI-UREA), THE MOST EFFECTIVE ANTIOZONANT

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Ethylenediurea (EDU) is an antiozonant, used by the air pollution research community over the last several decades. In order to summarize the current knowledge and discuss future perspectives, we reviewed an important amount of the available scientific evidence. EDU has been mostly applied to crops, mainly by the following three methods: a) spray, b) soil drench, and c) injection, each of which has advantages and disadvantages. EDU affects numerous physiological and biochemical parameters of plants, there is no specific response of plants to EDU, in some cases the evidence is contrasting, and its mode of action remains unknown. The antiozonate effect of EDU on plants seems to be species specific and it is not expected to cause side effects when applied at suitable doses. For this purpose, dose-response studies are required before the establishment of large-scale experiments. There is also a high need for EDU toxicological studies. With the accomplishment of toxicological studies, EDU can be applied with confidence as a phytoprotectant against ozone (O_3) deleterious effects. Furthermore, EDU plays a special role as a versatile tool in air pollution research. It can be used as a tool for (1) biomonitoring and assessment of O_3, (2) screening the O_3 sensitivity of wild plants, and (3) for studying the CO_2 and/or O_3 effects on plants in areas where the electricity is unavailable or in countries with financial limitations and therefore instrumental scarceness. In parallel, it is a potential tool for understanding the O_3 mode of action. We recommend EDU to be considered as a tool in studies dealing with screening of agrochemicals as potential protectants against O_3 and in studies carried out in controlled-environment chambers. The latter will allow the experimentalists to minimize the experimental error. From the literature review, we concluded that, overall, EDU is a much promising tool in research dealing with ozone effects on plants, and the relevant experimentations are highly encouraged.

TRENDS IN ATMOSPHERIC DEPOSITION LEVELS OF SOME ELEMENTS IN MACEDONIA

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Atmospheric trace element deposition in the Republic of Macedonia has been evaluated by using data from the national moss survey in 2010, comprising 47 elements in 72 samples of the pleurocarpous moss species *Homalothecium lutescens* and *Hypnum cupressiforme*. Three analytical techniques were used for the element determination: neutron activation analysis (NAA), inductively coupled plasma - atomic emission spectrometry (ICP-AES) and atomic absorption spectrometry (AAS). The results are compared with those obtained in the similar surveys carried out in 2002 and 2005 in order to evaluate temporal deposition trends [1-3]. From the comparison of the median and maximum values for the data obtained in 2002, 2005, and 2010 the levels of As, Cr, Cu, Fe, Sb, and Zn are showing the trend to decrease. Median values for Cd, Co, Ni, and Pb in 2005 are higher than in 2002 and 2010 that can be explained by the work of the lead-zinc smelter in Veles, not full abolishment of the leaded petrol at that time and the reactivation the ferronickel smelter in Kavadarci.

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ULTRASTRUCTURAL AND FUNCTIONAL CHANGES INDUCED BY ATMOSPHERIC POLLUTION IN *LUNULARIA CRUCIATA* L. (DUMORT.)

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The effects of pollution have been investigated in a metal-tolerant liverwort *Lunularia cruciata* L. (Dumort.) (Lunulariales), collected in two urban sites, by comparing gametophytes with samples collected in a rural, non-polluted area.
The two polluted sites are located in two highly contaminated urban areas: the downtown of Naples, and in the city center of Acerra, one of the tops of the Triangle of Death, an area in the South of Italy where a severe increase in deaths produced by cancer, heavily exceeding the Italian average has been observed for the last decades. This rise in mortality is thought to be provoked by high levels of pollution from illegal waste disposal by criminal organizations. As control, a unpolluted country site was chosen in the town of Riccia (Molise, Italy) that is far from big urban areas and industrial activities.

The liverwort *Lunularia cruciata* (Marchantiales) was used to evaluate the impact of metal(loid)s on a wide range of cellular responses, including changes in gene expression and transcription, as well as phytochelatin synthase activity: in this study, changes in ultrastructure and induction of phytochelatins, and Heat Shock Proteins 70 have been investigated and related to the different levels of pollution.
In both urban sites, cellular ultrastructure was strongly modified, and severe alterations were observed in organelles, in particular inducing marked alterations of the chloroplast structure. Simultaneously, strong increments in phytochelatins and Hsp70s were detected in gametophytes from both urban sites, compared with control samples. These effects are discussed in order to describe the response to pollution in *L. cruciata* in order to propose this liverwort species as a possible bioindicator able to measure the effects of atmospheric pollution on living organisms, particularly related to metal(loid) contamination.

STUDY ON BEAN AS A POTENTIAL BIOINDICATOR OF OZONE AND TRACE ELEMENTS IN AMBIENT AIR

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The aim of the study was to examine common bean as a simultaneous bioindicator of ozone and heavy metal in ambient air. For this purpose, in 2013 an experiment was carried out with *Phaseolus vulgaris* L.

Ozone-sensitive and -resistant bean genotypes were cultivated in the greenhouse for 6 weeks, and afterwards were exposed to ambient air for 28 days at three exposure sites, located in an urban, suburban and rural area. Two experimental series were conducted during the growing season. Number of pods, plant's height, leaf width and length were measured at the first, in the middle and at the end of each experimental period. The degree of ozone-induced visible leaf injury was also estimated. At the end of each experimental period the following trace elements were measured in leaves: lead, cadmium, nickel and arsenic.

Meteorological conditions were favorable to create ozone episodes. The accumulative concentration of ozone caused changes in plant morphological parameters. Lower biomass and higher number of pods were evidence of a defensive reaction, which was enhanced by the accelerated senescence process. Visible leaf injuries were observed only on leave of sensitive genotype. Trace element concentrations in leaves, absorbed from ambient air, didn't induce phytotoxic reactions. However, their concentrations varied significantly between sites, especially after second exposure series. Higher levels of nickel were noted at urban site, while lead and cadmium were higher in rural area. The results this study show that bean can be employed as a simultaneous bioindicator of ozone and heavy metal in ambient air. Both bean genotypes can be used as biomonitor of trace elements in air.

TOBACCO AS A POTENTIAL BIOINDICATOR OF OZONE AND TRACE ELEMENTS IN AMBIENT AIR

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This study presents the influence of tropospheric ozone and heavy metals on response of tobacco plants (*Nicotiana tabacum* L.). The main aim was to assess the application possibilities of the mentioned plant as a sensitive bioindicator of tropospheric ozone and cumulative bioindicator of heavy metals. During the growing season of 2013 studies were carried out using two varieties of tobacco: sensitive (Bel W3) and resistant (Bel B) to ozone. Plants were grown for 6 weeks in a greenhouse, then some of them were transported to the selected exposure sites, representing urban, suburban and forest conditions. Plants were exposed for 28 days of two series. On the last day of the experiment, samples were collected for laboratory analysis, which included: specific leaf area and other morphological parameters, including visible ozone-symptoms, and concentrations of zinc, cadmium, lead and copper in the dry mass of the leaves.

In response to the cumulative effect of tropospheric ozone, the plants responded with reduction of the growth of height and the length and width of leaves. Visible injuries of the leaf blades were observed only for ozone-sensitive tobacco. The differentiation of the average concentration of trace elements at different exposure sites was noted, revealed the possibility of using cultivated tobacco as a bioindicator of metals. However, it is hard to say which cultivar was better for trace elements indications, due to opposite results in each exposure series. Moreover, the results varied at exposure sites during the series. In the first series higher levels were noted at urban site than at sub-urban and forest, while in the second series was opposite tendency. Overall, tobacco could be, at the same time, use as a sensitive bioindicator of ozone and cumulative bioindicator of trace elements.

A SIX-YEAR EDU EXPERIMENT WITH AN O_3-SENSITIVE POPLAR CLONE

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Effects of ethylenediurea (EDU) after six years of exposure to ambient ozone (O_3) were examined in an O_3 sensitive poplar clone (*Populus maximoviczii* Henry *x berolinensis* Dippel). Every week over the growing season (annual average AOT40 was 23 ± 6 ppm h), trees were irrigated with either 450 ppm EDU, that is well known to protect plants from O_3 damage, or water. Sap flow, radial growth, plant phenological stage, visible ozone foliar injury, BVOC emission, plant height, stem diameter, biomass allocation to below and above ground, wood traits, leaf area and mychorrhizal infection were determined. Results show that EDU accelerated bud development and delayed early leaf senescence induced by O_3. EDU had a protective effects on O_3 visible injury because typical dark brown stipples were found more on leaves of WAT trees than of EDU trees. To assess the onset of O_3 visible injury, we calculated three O_3 indices: AOT40, POD0 and the ratio of stomatal O_3 uptake to net photosynthesis. The best metric to explain O_3 visible injury onset was stomatal O_3 uptake per net photosynthesis. EDU treatment increased coarse roots density, fine root length and stem diameter but did not increase the ratio of mycorrhizal infection in roots compared to the plants irrigated with water. In addition, the prolonged treatment with EDU did not induce a significant change in wood traits along the stem but decreased the water storage inside the stem, therefore the sap flow was higher in plants treated with water. Total BVOC emission, significantly decreased in damaged leaves at the end of the growing season but EDU treatment had no effect on BVOC emission.

IMPACTS OF ELEVATED OZONE AND TEMPERATURE ON WHEAT RHIZOSPHERE MICROBIAL COMMUNITIES

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Ozone (O_3) has increased significantly in recent decades as the result of anthropogenic activities. This gas is responsible for reductions in crop yields and plant biomass production of forest and grassland ecosystems. O_3 pollution, like other environmental stresses, can generate an oxidative stress into the plant affecting photosynthesis and plasma membrane. Rhizosphere microorganisms are in close relation with plant roots and feed on sloughed-off plant cells and organic compounds released by roots and, as a feed-back, they are involved in improvement of plant fitness. Little is known on the impact of elevated O_3 on rhizosphere microbial communities. Our objectives were to access O_3 and temperature impacts on wheat physiology, soil parameters and rhizosphere microbial communities' structure and activities. The experiment consisted in a 3-week fumigation with or without O_3 (70 ppb) of two different winter wheat cultivars (Soissons and Premio, obtained in 1988 and 2006, respectively) at two temperatures (20°C and 30°C). Samples without plant were used as controls. The effect of O_3 was measured on plant physiological parameters (biomass, CO_2 assimilation), on soil parameters (pH and DOC). Microbial communities' structure (bacteria, archaea and fungi) was evaluated by T-RFLP and qPCR. Functional diversity has been estimated by using catabolic profiling (MicroResp^{TM}). The results show a significant effect of ozone on plants (in particular by reducing their root biomass) in interaction with temperature (Premio was less resistant to O_3 at 30°C). Shifts in the microbial communities' structure were also observed under elevated ozone conditions, with a reduction of bacteria and increase of fungi. These changes were largely shaped by plant physiology and soil properties including pH and DOC. This study provides new insight into our understanding of the influence of O_3 and temperature on the interaction between plants and soil microbial communities.

MOSSES AS BIOINDICATORS OF AIR POLLUTION ALONG AN URBAN–AGRICULTURAL TRANSECT IN THE CREDIT RIVER WATERSHED, SOUTHERN ONTARIO, CANADA

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The activities associated with urbanization, such as vehicular traffic and industrial processes, lead to elevated emissions of atmospheric pollutants. Measuring the spatial extent of these pollutants is integral to identifying areas of concern and assessing mitigation measures. Bryophytes (mosses) are an effective bio-monitoring tool, as they exhibit morphological and physiological characteristics allowing them to accumulate a wide range of atmospheric pollutants. Further, they are broadly distributed across a range of habitats. The objective of this study was to evaluate the relative deposition of heavy metals and nitrogen using moss species along an urban–agricultural transition in the Credit River Watershed, southern Ontario. Moss species were sampled from Sugar Maple (*Acer saccharum*) dominated forest stands located within nature conservation areas (URL: www.creditvalleyca.ca) across the upper (U), middle (M) and lower (L) watershed regions (Figure 1). The watershed encompasses an area of 86,000 ha dominated by a combination of urban, rural and agricultural land uses. Thirteen species of moss were collected from sample sites (n = 12) across the study area (Figure 1), with only one moss species (*Atrichum altercristatum*) occurring throughout all regions. The concentration of Al, As, Cd, Cr, Cu, Fe, Ni, Pb, Sb, V, and Zn were determined using inductively coupled plasma mass spectrometry. Elevated concentrations of heavy metals were observed throughout the watershed; further, all metal concentrations were strongly correlated. The high metal concentrations may be the result of combined local and regional pollution sources. Local activities within each region such as agricultural tillage, construction, traffic and aggregate mining in conjunction with long range transport all play a role in atmospheric deposition.

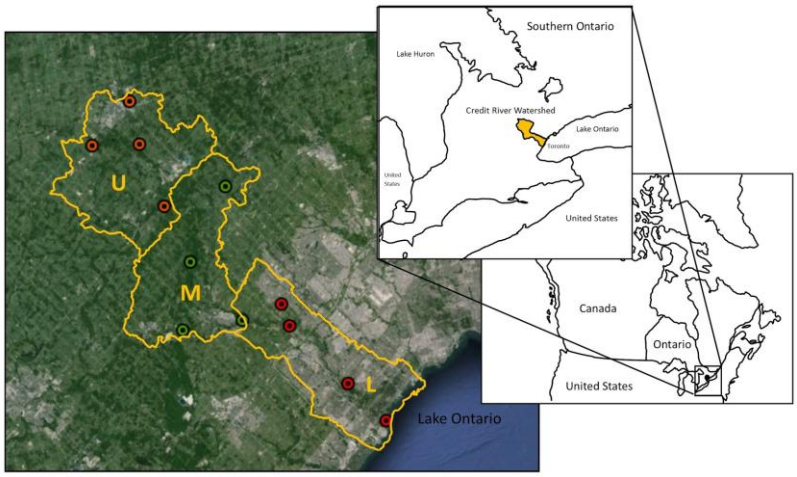

Figure 1. Location of the Credit River Watershed in Southern Ontario, Canada. The upper, middle and lower regions of the watershed are denoted by letters U, M and L, respectively. Upper (orange), Middle (green) and Lower (red) moss sample sites are depicted as filled circles (n = 12: four per watershed region).

NEW DATABASE FOR MOSS SURVEYS

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A database is being created for storage of information about the European moss survey conducting and storing analytical results on heavy metals, nitrogen, persistent organic compounds and radionuclides based on moss analysis. The database standardizes the stored data for subsequent statistical processing and building of distribution maps of elements over the sampled areas using GIS (geographic information system) technology. The database is of the network type. Database users can fill in, view and edit only their own information block. A restricted number of users will have access to the possibility of analyzing and sorting the full set of data. The management system *Microsoft SQL Server* is used for construction of the database. A database interface is created using integrated development environment *Visual Basic*. An adequate level of data protection will be provided as well as backup of the data on an external disk.

CHANGES IN ANATOMICAL AND PHYSIOLOGICAL PARAMETERS OF BEAN (*Phaseolus vulagris* L.) UNDER EXPOSURE TO TROPOSPHERIC OZONE

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The aim of this study was to evaluate anatomical and physiological changes of two genotypes of bean (ozone-sensitive S156 and ozone–resistant R123) under exposure to tropospheric ozone. Both genotypes were exposed to that factor in a suburban area (ambient air conditions). Similar set of plants was cultivated in a greenhouse (control conditions). Net photosynthesis rates (P_N), stomatal conductance (g_s) and intercellular CO_2 concentrations (C_i) were measured with CI-340 Photosynthesis System, every 7th day of the experiment. In order to assess cell death leaf tissues, Evans Blue staining was used. All samples were examined with a light microscope; micrographs were taken from each disc using a camera. Images were enlarged 40 times to allow observation of 1 cm^2 of leaf tissue and then, using a special computer software, percentage contents of dead, partially-dead and healthy cells in the entire measured surface (1 cm^2) were calculated.

The results showed variability in plants' response to tropospheric ozone influence, depending on their genotypes. P_N range for sensitive control plants was wider and amounted to 10.7-15.5 μmol (CO_2) m^{-2} s^{-1}, while for sensitive genotypes exposed to ozone these values fluctuated from 10.8-11.9 μmol (CO_2) m^{-2} s^{-1}. Intercellular CO_2 concentration (C_i) revealed opposite tendencies; higher values for ozone-exposed plants ranging from 108-133 μmol (CO_2) mol^{-1}, but (C_i) in control plants (both genotypes) ranged from 78-116 μmol(CO_2) mol^{-1}. Morphological examinations revealed many more visible injuries on leaves of the sensitive genotypes caused by tropospheric ozone; furthermore, growth and size of leaves were much lower than in resistant ones. There were no significant correlations between the examined genotypes with respect to the number of flowers and pods.

After 28 days of experiment, dead cells in leaf tissues of both ozone sensitive and resistant beans were stained from dark to light blue depending on the stage of cell membrane degradation. In leaf tissue of ozone sensitive genotypes, many more dead cells were detected, than in ozone resistant ones.

The correlation between the results of photosynthetic activity and cell death assessment showed anatomical and morphological differences between the resistant and sensitive genotypes of bean under ozone influence.

ASSESSMENT OF POTENTIAL DRIVERS FOR THE RELEASE OF NO FROM THE SOIL IN A SUBALPINE FOREST

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An automated dynamic chamber system for measure NO fluxes from the soil has been installed during 2012 and 2013 at the JRC forest site in Ispra (VA-Italy).
Air temperature and humidity probes were also placed in each chamber and several parameters have been monitored during the experimental season such Soil Temperature (TSoil) and Soil Water Content (SWC) in order to study potential drivers for soil fluxes of NO
Our results are similar to those collect at several European forest site both for dry and wet soil on middle and long term (1 year or more) measuring campaigns. Comparing literature describing short term continuous measurements (few weeks) in similar conditions is possible note that some different (lower NO average soil flux in this case) are recorded.

Soil NO emission clearly go down as soil temperature decreases and the pattern changes as well significantly during and after rain events that cause a steep increase of the SWC.
These results can be explained through several indicators of soil microbial activity, such as respiration, that are positively related to temperature.

NO fluxes increase with soil temperature in sufficiently wet condition and this seems to be confirmed by our data. In our experiment we also found a negative correlation between NO fluxes and SWC during very wet soil conditions. Soil water content at our site ranged widely from dry soil to water saturated soil values, in particular after heavy rain fall episodes.
However in our experiments large emissions of NO from soil after rainfall, due to a sudden mineralization of nutrients accumulated during dry period as reported in the literature are not so evident.

While in our experiments we have found a rather strong seasonal pattern regarding NO fluxes from soil, the SWC was rather constant throughout the year and only went up to 70% during some period between May and June. This episode has been followed in the days after by higher NO fluxes. These fluxes could also be explained from others concomitant conditions like high Tsoil and high level of microbial communities present during this specific season.

RESPONSES OF FOUR COMMON URBAN TREES IN CHINA TO ELEVATED OZONE

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Potted plants of *Ailanthus altissima* (Mill.) Swingle (AA), *Fraxinus chinensis* Roxb. (FC), *Platanus orientalis* L. (PO), and *Robinia pseudoacacia* L. (RP) were exposed to enhanced ozone levels (NF+40, averaged O_3 concentration of 69 nmol mol^{-1} from 09:00 to 18:00) in Open Top Chambers. These species are among the most common ornamental plants in streets, gardens and tree plantations in most Chinese cities, where ozone precursors such as NO_2 are steadily increasing. Ozone induced visible injury in all species as well as microscopic alterations such as thickening of the cell walls, collapse of the palisade parenchyma cells, callose accumulation or chloroplast degradation. Ozone-induced symptoms were consistent with those observed the same year in the field in three of the species (AA, FC, RP; Feng et al., 2014, Environ. Pollut. 193:296-301). Ozone reduced the maximum activity of Rubisco ($V_{C,max}$) or the maximum electron transport rate (J_{max}) in PO and FC already in August, before any significant change in light saturated CO_2 assimilation (A_{sat}) was detected. In September, A_{sat} declined between 11% and 31% in all species, and also stomatal conductance (g_s) in AA (-37%) and RP (-34%). Changes in fluorescence parameters were also observed in PO and RP. Although there was a consistent tendency towards a reduction in chlorophylls and carotenoids due to the effect of ozone, changes induced by this pollutant were not statistically significant. In all species, Total Antioxidant Capacity (TAC), phenols and ascorbate (total and reduced) content significantly increased after ozone exposure. These leaf-level effects were however not reflected in significant changes in biomass parameters. Longer experiments involving several growing seasons are needed in order to assess how chronic ozone concentration might affect the different biomass components and water use in these species.

A DOSE-RESPONSE RELATIONSHIP FOR YOUNG HOLMOAK TREES EXPOSED TO DIFFERENT LEVELS OF OZONE DURING ONE GROWING SEASON

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An Open-Top Chambers (OTC) experiment with different ozone treatments was performed on young trees of *Quercus ilex* from April to September 2013 in Northern Italy (Curno).
Forty-eight 3 years old plantlets, homogenous in size and provenance, were potted and placed in 12 Open-Top Chambers arranged in 3 randomized blocks where ozone was applied at 4 different levels (CF -40%, NF, NF+30%, NF+74%). Soil was kept close to field capacity during the whole duration of the experiment to avoid water stress.
At the end of the experiment all the plants were harvested and dry biomass production was separately assessed for stems, roots and leaves after a 48 hours oven drying.
The stomatal ozone dose was calculated following the parameterisation of stomatal conductance published in the UN-ECE Mapping Manual for Mediterranean evergreen species, but with a slightly higher g_{max} value, calculated from gas-exchange measurements performed in June and September. The latter measurements were also used to check the model fit.
The 99th percentile of the measured stomatal conductance to water vapour, when CO_2 concentrations were between 350 and 450 ppm, was 358 mmol m^{-2} s^{-1}, and it was taken as g_{max} in the stomatal model. This value is about 90 units greater than the value proposed by the UNE-CE Mapping Manual.
In the ozone enriched treatments (NF+30% and NF+74%) plants showed a quite generalized biomass reduction, more intense in the roots, which presented a 27% decrease in the NF+74% treatment. Stems biomass and leaves biomass for the same treatment showed respectively a -16% and a -17% reduction.
The relationship between ozone exposure (daylight AOT40) and the biomass reduction was significant ($p<0.05$) for roots and showed a 5% of biomass decrease every 10'000 ppb.h of AOT40 ($R^2=0.39$). A similar relationship for stems biomass was slightly less significant ($p<0.09$), while for leaves biomass was not significant ($p<0.16$).
The dose-response relationship based on the O_3 stomatal flux (POD1, Phytotoxical Ozone Dose over a threshold of 1 nmol O_3 $m^{-2}s^{-1}$) absorbed by plants through stomata was significant for the total biomass ($R^2=0.3824$, $p<0.05$), for root ($R^2=0.3871$, $p<0.05$) and for stem biomass ($R^2=0.4785$, $p<0.05$), but not for the leaves ($R^2=0.1849$, n.s.).
The proposed dose-response relationship reports a 6% of total biomass reduction every 10 mmol m^{-2} of POD1 increase, a similar value of reduction is also predicted for the root biomass, while for the stems biomass a 4.5% decrease every 10 mmol m^{-2} of POD1 increase is expected.
These results suggest a POD1 Critical Level of 7 mmol O_3 m^{-2} for Holmoak protection corresponding to an accepted 4% reduction of the total biomass.

ASSESSMENT OF VERTICAL ELEMENT DISTRIBUTION IN STREET CANYONS OF BELGRADE AND MOSCOW USING MOSS TRANSPLANT TECHNIQUE

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Sphagnum girgensohnii moss bags were used to study small-scale vertical distribution of some major and trace elements in different types of street canyons (regular, deep and avenue types) in Belgrade and Moscow urban areas. The exposure time was 10 weeks during the summer of 2011. Exposure of the moss bags was at three different levels to test differences in deposition patterns according to height. The differences between street and off-street sides in vertical element distribution in Moscow were tested too. Contents of 25 major and trace elements in moss were determined by instrumental neutron activation analysis. The results showed that accumulation of elements in the exposed moss bags was higher in deep and regular street canyons in comparison to avenues, the latter even with higher traffic flow. Element contents were the highest at the lowest heights. Most of the determined element contents were lower on the off-street avenue side compared to the on-street side for all heights of moss exposure. The results obtained indicate that *S. girgensohnii* moss bags may reflect small-scale variations of the total concentrations of elements.

a*POD* - **A**PPROXIMATE ***P***HYTOTOXIC ***O***ZONE ***D***OSE: A SIMPLIFIED CONCEPT TO EVALUATE THE O_3 RISK AT LOCAL SCALE

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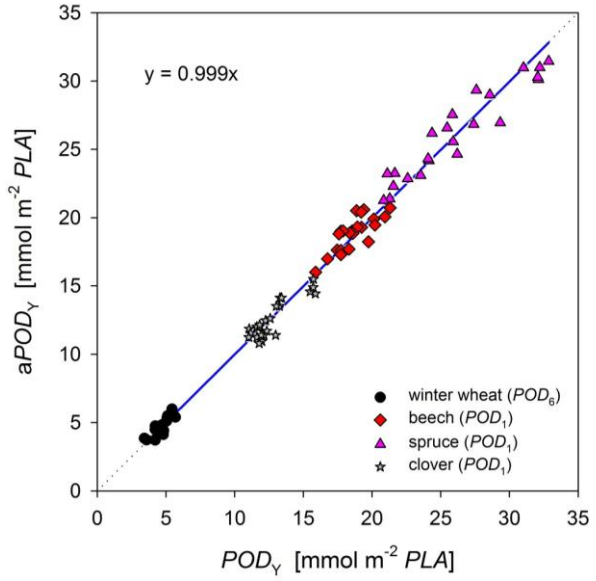
The European air quality guideline for O_3 requires measurements of O_3 concentrations at local scale (EU, 2008). Additionally, Annex V of COM (2013) 920 final (EC, 2013) requires the monitoring of O_3 at representative monitoring sites. At these sites, the O_3 risk for vegetation growth and biodiversity has to be assessed by the exceedance of flux-based critical levels. Because the O_3 concentrations measured at a standardized reference height have to be transformed to that at canopy height, the monitoring stations have to fulfill the requirements for applying micrometeorological models. They have to be regional representative (EU, 2008), should be established above short grass for climatology reasons (WMO, 2001) and should have an adequate fetch (VDI 3786 sheet 13, 2006). Normally, air quality monitoring stations do not fulfill all these requirements. Additionally, not all meteorological input parameters needed for the POD_Y approach are measured at the air quality monitoring stations with an adequate quality.

Therefore, we develop an approximate approach for the POD_Y indices during the research program "Biodiversity and Ozone" (FKZ: 3711 63 235, German Federal Environment Agency). The calculation is based only on measurements of O_3 concentration and air temperature. Radiation is estimated as a function of maximum possible radiation, air temperature and relative humidity, which itself is calculated as a function of radiation and air temperature. For both model input parameters, seasonal regression models were derived for each hour during daytime. Furthermore, the laminar layer resistance is set constant. The so-called **a**pproximate ***P***hytotoxic ***O***zone ***D***ose, a*POD*, can be interpreted as an indicative measure for local O_3 risk assessments. The performance of the approach is illustrated below. The figure is based on calculations for up to 23 monitoring stations distributed over Germany.



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BIOINDICATION OF HEAVY METALS ATMOSPHERIC DEPOSITIONS IN THE SOUTHEAST COAST OF THE BALTIC SEA (KALININGRAD REGION)

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The moss biomonitoring technique was applied to air pollution studies in the West region of Russia (Kaliningrad region). Kaliningrad region - the west part of Russia is situated on the South-East cost of Baltic sea, between Poland and Lithuanian. The square of continental territory is 13300 km^2. There are only 17% of the territory is covered by forest.
Samples of the terrestrial mosses *Pleurozium schreberi* and *Hilocomium splendens* have been collected every 5 years, from 2000 in accordance with the sampling strategy of the European moss survey program.
Atomic Absorption Spectrometry was used for determination of metals fraction. Such metals as Pb, Cd, Cr, Ni, Cu and Ag were determined by AAS technique with ETA

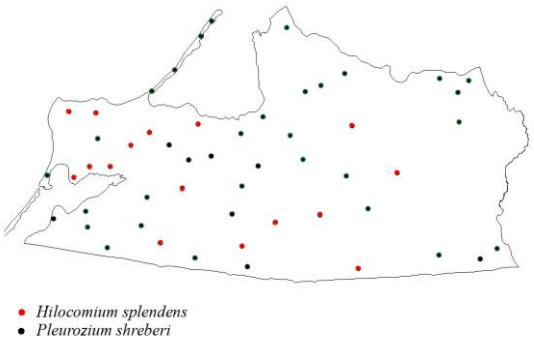

Table - Fraction of metals in collected samples of mosses in Kaliningrad region (mg/kg DM)

	Pb	Cd	Cu	Ni	Cr	Ag
mean	2,35	0,213	5,00	1,44	2,48	0,036
mediana	1,83	0,140	3,17	1,25	1,64	0,026

The values of metals vary widely, but low values prevail. Highest concentrations were determined in the west part (Sambia peninsula), lowest ones in the center of region.

Principal component factor analysis was used to identify and characterize different pollution sources and to point out the most polluted area in 2010. There were identified two factors of metals emission: PC 1 (42,7%) >0.6 (Cu, Cd); PC 2 (20,7%) >0.6 (Cr, Ni, Fe)

The PCA of metal concentrations in mosses show that the Sambia peninsula and South-West part sites have higher metal concentrations than other sites
Cartography analysis revealed spatial patterns of metals distribution. There are highest levels of metals in mosses in the west part of region (Sambia peninsula) and elevated levels in the North, North-East and South-West.

POSSIBLE MECHANISMS FOR THE PROTECTIVE ACTION OF THE ANTIOZONANT ETHYLENEDIUREA (EDU) IN OZONE-SENSITIVE AND OZONE-TOLERANT PLANT SPECIES

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Ethylenediurea (EDU) is an antiozonant compound known to prevent ozone (O_3) damage to leaf tissues in many plants. The mechanism by which EDU protects plants remains unclear. Time-course experiments were conducted to examine the effects of EDU and O_3 on the antioxidant scavenger system of the leaf in four plant species differing in O_3 susceptibility: Jew's mallow (Corchorus olitorius) [very sensitive], white clover (Trifolium repens cv. Masry) [sensitive], romaine lettuce (Lactuca sativa cv. Paris Island Cos) [intermediate], and cotton (Gossipium barbadense cv. Giza 70) [tolerant].

The exposure to O_3 at 100 ppb for three days (6 hrs per day) caused the appearance of extensive injury symptoms on sensitive species especially on the oldest fully expanded leaves, a decrease in the photosynthetic capacity of the leaf (80%-29%) and stomatal conductance (86%-25%) and a loss in total chlorophyll and carotenoids pigments. All these effects were limited or avoided by a pretreatment with EDU as a soil drench (50 mg/pot).

Effects of O_3 and/or EDU on the activities of the antioxidative enzymes superoxide dismutase (SOD) and glutathione reductase (GR) were examined at different times (zero, 2,6,24,30 hrs) through the course of two O_3 fumigation sessions (6 hrs of 100 ppb O_3 per day). The protein levels of the different SOD isozymes were also investigated. In the two sensitive species Jew's mallow and white clover both SOD activity and levels of its chloroplastic (SOD-1) and cytosolic (SOD-2,SOD-4) transcripts were increased by O_3 and EDU singly. When O_3 and EDU were used simultaneously this increase was markedly less or was not found. This pointed to a counteractive effect of EDU against O_3 induced oxidative stress in those species. The intermediate species, romaine lettuce, had only one SOD isozyme band, cytosolic SOD-2 and SOD-4, which decreased in response to O_3, EDU or O_3+EDU treatment. SOD increased only at the end of the second fumigation and was thought to coincide with the onset of injury to leaf tissue. The resistant plant species, cotton, contained only chloroplastic SOD-1. Both the SOD activity and the quantity of the isozyme protein increased in response to O_3 and EDU when used separately and showed a greater activation when used in combination. GR activity was stimulated in all cultivars only during the second fumigation period.

Results suggest that significant differences exist between sampling times and thus points to the error in considering EDU effects on the basis of one single ozonation.

The effect of the antiozonant EDU in inducing ozone tolerance may be due in part to a direct or indirect effect on the antioxodative defense mechanisms of the leaf.

CRITICAL EVALUATION OF ECOSYSTEM POLLUTION

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Pollution problems in the forest ecosystems resulting from 100year of operation of three smelter complexes in the Central Spiš are reviewed. Original data are presented with respect to temporal and spatial trends of nitrogen, sulphur, and heavy metal pollution. INAA at the IBR-2 reactor has made it possible to determine the content of 40 elements in mosses, foliage of forest tree species, lime and spruce wood, soil and wildlife in marginal Slovak hot spot - Central Spiš. Instrumental neutron activation analysis (INAA) at the IBR-2 reactor has made it possible to determine the content of 40 elements in mosses, foliage of forest tree species, lime and spruce wood, soil and wildlife in the marginal Slovak hot spot – the Central Spiš. In addition to NAA, flame atomic absorption spectrometry (AAS) was applied to determine the contents of S, Cd, Cu, Hg and Pb. The polluted air impact on forest ecosystems is a major question at present and in the future. 1.7-fold exceeding of critical values and high concentrations of As, Fe, Hg, and N in spruce needles were found in the Central Spiš. The Low Tatras National Park served as a pristine (baseline) region. The concentration of Hg and As in humus and horizont A_o from Central Spiš is increased markedly. Other determined elements (Cd, Co, Cu, Ni, Pb, and Zn) do not exceed the limits. In the area of Central Spiš we have found in comparison with the Norwegian limit values (the Central Norway- as relatively pristine region) exceeded levels for Al, As, Ca, Cd, Cl, Co, Fe, K, Mn, Sb, Sm, Sr, W, and Zn. In comparison with Magnitogorsk in the Ural Mountains (the most polluted area in Europe) we found in Spiš higher values for Ca, Cl, Co, K and Mn. We found the highest concentrations of Au, Br, Co, and Sb in the oldest 70–80 years old spruce wood, and the highest concentrations of Al, As, Au, Br, Cl, K, Na, Rb, Sb and Sm in the oldest 80–90 years old lime wood. We found the highest concentration of Al, As, Ba, Br, Ce, Co, Cr, Cs, Fe, Hf, Hg, K, La, Mg, Mo, Na, Ni, Pb, Rb, Sb, Sc, Sm, Ta, Tb, Th, U, V and W in soil samples; the highest concentration of Ca, Cd, Cl and S in spruce roots; Mn and S in spruce needles; Sr in mosses and Zn in lichens. In comparison with limit values the concentration of Ba, Co, Hg, Mg, Mn, and Sr in the teeth of roe deers is increased markedly. Other determined elements (Al, As, Ca, Cd, Cu, Fe, Na, Pb and Rb) do not exceed the limits.

Key words: air pollution, biomonitoring, metals, foliage, mosses, soil, wood, wildlife

STRUCTURAL CHARACTERISTICS OF *QUERCUS ILEX* L. AS A TOOL FOR MODELING POLLUTANTS REMOVAL IN URBAN AND PERIURBAN FORESTS OF ROME.

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Urban ecosystems have received increasing scientific attention because of the growing impact of urbanization on the natural environment. Since the relationships between ecosystem health and human well-being is well-established, the Green Infrastructure (GI) approach ought to offer a way to develop planning strategies to manage the urban sprawl. Indeed the concept of GI has been introduced with purpose of coherently planning urban and periurban green space. GIs comprise all natural, semi-natural and artificial networks of multifunctional ecological systems within and around urban areas, emphasizing their multifunctional role. GI can provide a range of Ecosystem Services (ESs) which, in turn, depend on vegetation structure and functions. Among GIs, urban forests have a pivotal role in the delivery of several important ESs as air quality amelioration and micro-climate regulation. Since the spatial heterogeneity of urban forests influences the amount and quality ESs they provide, fine scale strucutural surveys are necessary. In the present work, included in the TreeCity project, a detailed scale study was carried out in the Metropolitan area of Rome aiming at describing structural features of forests in urban and periurban contexts. The obtained results have shown differences in the main structural parameters: diameter at breast height, stem density and crown area. Perhaps, such differences are the consequence of different stressful condition and management among the two experimental sites. The highlighted differences can have important outcome in quantification of ESs provided by the urban and periurban forest. The structural parameters collected in the field will be used to parameterize a SVAT type model (GOTILWA+) allowing to evaluate the contribution of vegetation to air quality improvement, and the ability of urban vegetation to withstand different environmental conditions.

THE ENVIRONMENT SITUATION OF THE ALBANIAN COASTAL AREA BASED ON THE ASSESSMENT OF TRACE ELEMENTS DEPOSITIONS BY USING MOSSES AS BIOINDICATORS AND SEA EFFECT ON THIS ASSESSMENT

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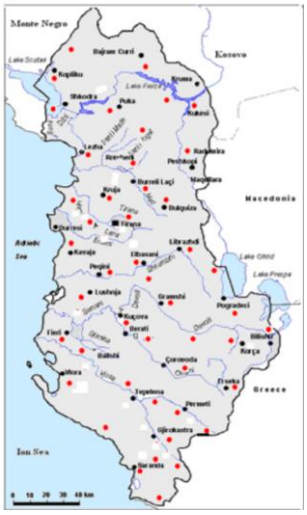
The atmospheric deposition of Al, Fe, Li, Na, As, Cr, Fe, Ni, V, and Zn in the Albanian coastal area was investigated by using carpet-forming moss species (Hypnum cupressiforme) as bioindicators that is done as a part of the international program (International Cooperative Programme (ICP) Vegetation, UNECE) carried out in most European countries since 1987.

Sampling was carried out during the dry seasons of autumn 2010 and summer 2011 at sites distributed all over the Albanian coastal area. Unwashed, dried samples were totally digested



by using microwave digestion, and the concentrations of metal elements were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES).

The results reflect local emission points. Only the elements with high values of concentration are compared to other European countries and are discussing here. High median concentrations for Al, Fe, Cr, Ni and V the in mosses were found in Albania. The median values of chromium (4.75 mg/kg, dry weight (DW)), iron (1,618 mg/kg, DW), nickel (5.85 mg/kg, DW), vanadium (3.51 mg/kg, DW), zinc (13.77 mg/kg, DW), and aluminum (6,974 mg/kg, DW) are similar to those of neighboring countries but higher than those of European countries.

Table Fraction of metals in collected samples of mosses in coastal areas (mg/kg, DW)

Element	As	Cd	Li	Sr	V	Zn	Ni	Pb	Cr	Cu	Mn	Na	Al	Ca	Fe	K
Mean	0.541	0.17	1.644	22.19	4.23	14.06	11.36	3.28	6.38	6.07	70.45	94.54	1958	7094	1892	3736
Median	0.305	0.10	1.425	21.71	3.51	13.77	5.85	2.41	4.75	5.58	56.34	87.13	1638	6734	1618	3414

An exponentially weighted moving average (EWMA) and univariate control chart was used to investigate the moving range of successive observations and to estimate the variability of the data. Certain local emitters were identified like the iron-chromium metallurgy and cement industry, oil refinery, mining industry, and transport. In addition, natural sources, such as the accumulation of these metals in mosses caused by metal-enriched soils, associated with the wind blowing soils particularly in the southeast direction of the country, were pointed as another local emitting factor. The sea effect is studied through the Na variation in moss samples in whole territory of the country. The highest Na content were found close to coastal area

INFLUENCE OF OZONE ON R123-S158 SNAP BEAN GENOTYPES UNDER AMBIENT AIR IN ATHENS, GREECE

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Ambient ozone is considered an insidious threat for cultivated plants because it occurs at higher concentrations during the growing season for the majority of them. Sensitive to ozone genotypes, of several plant species (e.g. *Nicotiana tabacum* cv. Bel-W3, white clover (*Trifolium repens* L. cv. Regal, etc.) have been used as ozone-bioindicators. The ozone-sensitive (S156) and ozone-resistant (R123) genotypes of *Phaseolus vulgaris L.* have been suggested as a good bioindicator tool for the evaluation of ambient ozone effects on plant yield.

In order to test the performance of this tool under Greek environmental conditions (following the protocol of ICP vegetation), we grew up plants of S156 and R123 genotypes (8 plants per genotype per year) under field conditions in Athens, during the growing seasons (early June to late October) of the years 2012 and 2013. Several parameters were measured among which yield and stomatal conductance (g_s).

The nested design ANOVA showed that there was a statistically significant difference between genotypes ($p<0.0001$) and between years ($p<0.0001$) and a significant ($p<0.0001$) genotype × year interaction. The pods' bulk and seeds dry masses were lower in the year 2012 in comparison to the year 2013. The between the years difference was partly attributed to a small difference in the meteorological conditions; analysis of meteorological data revealed that the year 2012 was slightly warmer and drier. Besides, the ozone levels, in terms of AOT40, over the entire growing period for both years were similar (1736 *n*l l^{-1} h for the 2012 and 17171 *n*l l^{-1} h for the 2013). However, the ozone level during July was about 35% higher in 2012 compared to 2013. It seems that the ozone levels during July were enough crucial to affect the final plant yield. The yield reduction was higher for the S156 genotype in comparison to the R123.

In both genotypes, g_s was higher in the lower leaf surface than in the upper one ($p<0.0001$). Nevertheless, there was no any significant difference in the g_s between the two genotypes either in the abaxial or in the adaxial surface.

The experiment confirmed that S156 & R123 pair of snap bean genotypes performed quite well under Greek conditions. The ozone levels during July - when the plants were fully functioning - were more crucial in determining the plant yield.

PRELIMINARY RESULTS OF ATMOSPHERIC DEPOSITION OF MAJOR AND TRACE ELEMENTS IN THE GREATER AND LESSER CAUCASUS MOUNTAINS STUDIED BY THE MOSS TECHNIQUE AND NEUTRON ACTIVATION ANALYSIS

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Sixteen moss samples (*Hypnum cupressiforme* Hedw. – 1; *Hylocomium splendens* Hedw. – 8 and *Pleurozium schreberi* Brid. – 7) have been collected along altitudinal gradients in the Caucasus mountains covering foothill, forest, subalpine and alpine belts in the range of altitudes from 600 m to 2665 m. Concentrations of Na, Mg, Al, Cl, K, Ca, Ti, V, Mn, Fe, Zn, As, Br, Rb, Mo, Cd, I, Sb, Ba, La, Sm, W, Au, and U determined by neutron activation analysis in moss shoots for 2011–2014 growth period are reported. Multivariate statistical analysis of the results obtained did not reveal any pollution sources in this part of the Caucasus mountains, considered *a priori* as a pristine area. A remarkable increase in concentrations of all elements with rising altitude was observed. Most pronounced it was for the light and heavy crust elements. The most obvious explanation of this phenomenon is that the content of mineral soil particles on the moss is increasing with altitude due to gradually disappearing vegetation cover. This means an increasing frequency of barren areas from which soil particles may be released by wind erosion and physically captured on the moss surface as previously observed in Arctic ecosystems [1]. Comparison with the available concentrations of such elements as V, Fe, Zn, As, and Cd for the same altitude (~ 2500 m) in moss collected in the Alps [2] indicates that all sampling sites in that work probably had a sufficient plant cover on the ground to prevent soil erosion.

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VEGETATION AND ECOSYSTEM SERVICES: A PILOT STUDY TO ESTIMATE PM AIR POLLUTION REMOVAL IN PERIURBAN MEDITERRANEAN FOREST OF CATELPORZIANO ESTATE

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Urban and peri-urban vegetation provide a large array of Ecosystem Services which can improve inhabitants quality of life. Air pollution, due mainly to car traffic and building's heating systems, is one of the major environmental and public health problems in the densely populated areas. Moreover Trees and shrubs, acting as a sink of pollutants, can contribute significantly to abate airborne pollutants, sustaining one of the most important environmental services offered by green. Among air pollutants, PM_{10} (particulate matter less than 10 micron) and $PM_{2.5}$ (particulate less than 2.5 micron), represent one of the major environmental threats, especially for human health; in fact several studies point out correlations between air pollutants and serious respiratory and cardiovascular diseases, suggesting that some premature deaths could be attributed to the air pollution. Vegetation may have an influence on PM concentration through different mechanisms as direct particles absorption on plant surfaces, or modification of natural air streams, so enhancing turbulence and favoring mixing of polluted air with clean air (dilution).

Results showed here are part of a larger project aimed to investigate and deepen the effect of Mediterranean forest of Castelporziano Estate (Rome, Italy) on ambient PM concentrations. Some experimental field campaigns were performed with the support of a fire tower. Measures were recorded above e below the forest canopy at the same time, using two OPC-Optical Particle Counter- (Aerocet 531, Metone USA).

Time-course data showed a similar daily trend for PM_{10} and $PM_{2.5}$, but it is interesting to notice that high concentration of PM - both course and fine fraction- occurred during the nighttime and when the PBL –Planetary Boundary Layer- decreases, indicating a potential transport of polluted air coming from the neighboring urban area of Rome (about 20 km far), emitted in the city during the day. A first estimation of PM abatement percentage between above and below the forest canopy is also given. The obtained results could improve the characterization of the PM in the Castelpoziano Estate area, which has a very specific environmental condition due to vicinity with the Metropolitan area of Rome. Further studies aimed to quantify the capability of plants to abate airborne pollutants as PM will be necessary to pointing out the crucial role of the vegetation in improve air quality, particularly in urban and periurban areas.

MODELLING EFFECTS OF OZONE ON PHOTOSYNTHESIS OF FLAG LEAVES IN WINTER WHEAT

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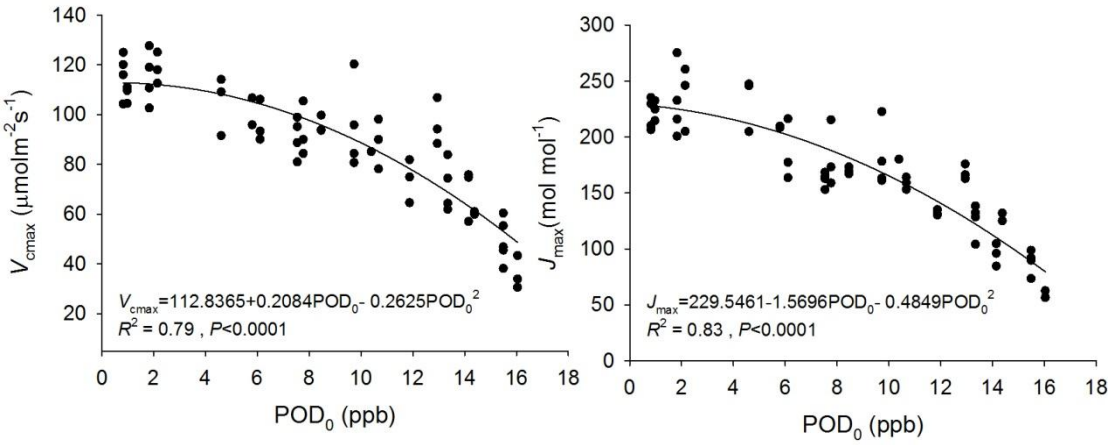
Current studies have suggested ozone effects on photosynthesis might be due to two aspects: 1) Limitation of stomatal conductance; 2) Photochemical reaction. However, to model ozone effects on photosynthesis has to be studied in combination of stomatal and non-stomatal factors. In this study, stomatal conductance was firstly simulated based on Jarvis model, then stomatal ozone flux and intercellular carbon dioxide concentration were simulated. The changes of photosynthetic parameters (i.e. Vcmax, Jmax, gm, Γ*) with stomatal ozone flux were uncovered. Instead of previous studies on the linear quantitative relationship between the change of Vcmax and ozone flux, we found the nonlinear quantitative relationship between Vcmax, Jmax, gm and the dose of ozone. The results will help us to illustrate the mechanisms of ozone affecting leaf photosynthesis.



The quantitative relationships between parameters and ozone flux

THE IMPACTS OF CLIMATE CHANGE AND NITROGEN DEPOSITION ON FOREST HEALTH CONDITION

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Climate change and air pollution are two significant stressors affecting forest health and vitality of European forests and are highly relevant for sustainable management of European forests. Several studies identified adverse impacts of atmospheric nitrogen deposition on forest tree growth (de Vries et al., 2006, 2009), vegetation composition (Gilliam, 2006) and plant diversity (Bobbink et al., 2010). In this framework, evaluation of crown defoliation, an indicator for forest health and one of the most important parameters monitored in the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is essential. The study aims to estimate crown defoliation in 2030, under three climate and one nitrogen deposition scenarios, based on evaluation of the most important factors (meteorological, nitrogen deposition and chemical soil parameters) affecting defoliation of twelve European tree species. The methodological approach consists in the use of the Random Forests Analysis (RFA) and general regression models (GRM). Modelling of crown defoliation is a challenge at European scale because crown defoliation integrates a wide range of mutually interacting predictors, mutually varying in the space and time.
The combination of favorable climate and nitrogen fertilization in the more adaptive species induces a generalized decrease of defoliation. On the other hand, severe climate change and drought are main causes of increase in defoliation in *Quercus ilex* and *Fagus sylvatica*, especially in Mediterranean area. This study provide information on regional distribution of future defoliation, an important knowledge for identifying policies to counteract negative impacts of climate change and air pollution.

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HEAVY METAL AND NITROGEN CONCENTRATIONS IN MOSSES IN IRISH ATLANTIC OAK WOODLANDS

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The objective of this study was to evaluate the relationship between moss chemistry and indices of atmospheric deposition in Irish Atlantic oak woodlands. Moss species were collected from thirty-nine *Quercus petraea-Luzula sylvatica* woodlands (Irish National Survey of Native Woodlands: Perrin 2008) during April 2013; at twenty-five of these sites *Isothecium myosuroides* and *Thuidium tamariscinum* pleurocarpus moss species were sampled (Fig 1). Both species were analysed for % CNS (Elementar vario Marco CNS analyzer) and for heavy metal concentrations using ICP-MS following microwave digest (Mars 6 digester; EPA method 3052).

The %N moss content ranged from 0.65−1.94% (mean = 1.23%, median = 1.06%) in *Isothecium* and 0.83−2.28% (mean = 1.34%, median = 1.39%) in *Thuidium*. The %N content was correlated between species ($r = 0.82$, $p < 0.001$), but their mean value was significantly different ($t = 2.1$, $p < 0.05$). A simple linear regression suggested that %N moss content was significantly related to atmospheric ammonia (NH_3) for both species (Figure 1). Few heavy metals had strong interspecies correlation (As: $r = 0.86$, Pb: $r = 0.76$, Sb: $r = 0.61$), and none were related to atmospheric deposition. However, several metals were positively correlated with easting and northing (Cu, As, Cd, Sb and Pb) for both species, indicating higher metal concentrations in the east and north east. Previous studies have shown higher acidic deposition associated with easterly air masses suggesting transboundary or national industrial sources, which are primarily located along the eastern seaboard.

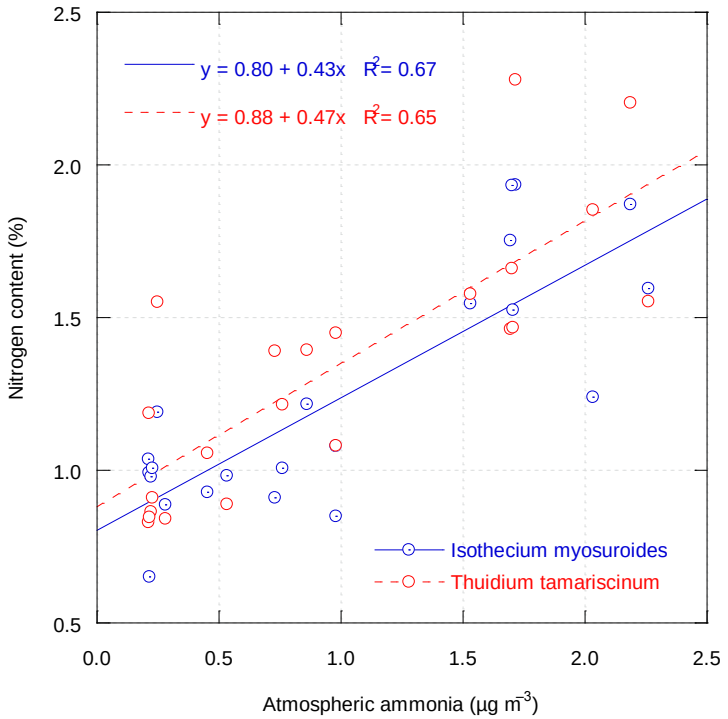

Figure 1. Nitrogen content (%) in two moss species (*Isothecium myosuroides* and *Thuidium tamariscinum*) against atmospheric ammonia (NH_3) concentrations (µg m^{-3}).

IMPACTS OF SOIL MOISTURE ON DE-NOVO MONOTERPENE EMISSIONS FROM EUROPEAN BEECH, HOLM OAK, SCOTS PINE AND NORWAY SPRUCE

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Biogenic volatile organic compounds (BVOC) are important atmospheric trace gases. They are released from plants into the surrounding atmosphere and are involved in photochemical ozone and particle formation. For this reason BVOC impact the oxidation capacity of the troposphere. The release of BVOC is frequently associated with a range of biotic and abiotic stress factors. On a quantitative basis, the most important BVOC are isoprenoids such as isoprene and monoterpenes. Isoprene and monoterpene emissions from trees originate from the synthesis of complex molecules from simple molecules (*de-novo* biosynthesis) in a light- and temperature-dependent manner and environmental conditions can have a strong influence on their biosynthesis. For this reason, impacts of soil moisture on *de-novo* monoterpene (MT) emissions from Holm oak, European beech, Scots pine, and Norway spruce were studied in the laboratory. The results showed that mild drought caused only slight increases of MT emissions. The increases were explainable by increasing leaf temperature due to lowered transpirational cooling and by recovery from a preceding hard drought. Severe drought decreased MT emissions to almost zero. Re-watering the plants caused increasing emissions until the same levels were reached as before the drought stress, implying that impacts of drought were reversible on a time scale of days. To incorporate impacts of soil moisture on *de-novo* MT emissions into the Model of Emissions of Gases and Aerosols from Nature (MEGAN), the volumetric water content of the soil, Θ, was used as a reference quantity. As long as Θ was > 0.2 m^3/m^3, emissions were not directly affected. With Θ below a certain threshold, MT emissions decreased simultaneously with Θ. The relationship between Θ and MT emissions was to a good approximation linear, allowing the determination of Δ Θ 1 (the range of Θ where the emissions drop from their maxima to zero). As average from 7 independent replicates was found Δ Θ 1 = 0.08 m^3 / m^3 with a standard error of 0.02 m^3 / m^3. There were no systematic differences of Δ Θ 1 between Mediterranean Holm oak and trees from boreal and temperate forests. The value Δ Θ 1 = 0.08 m^3 / m^3 was therefore used in MEGAN. It was also tested whether a factorial approach, such as the one used in MEGAN, was suitable to describe the soil moisture dependence of de-novo MT emissions. Using Holm oak the temperature and light intensity dependence of the emissions was measured for well watered plants and during severe drought stress. No substantial interdependencies were found, indicating that the approach used in MEGAN for isoprene is also suitable for de-novo MT emissions. Describing the soil moisture dependence using Θ as a reference was unsuccessful in case of sudden soil moisture changes. Re-watering the plants after severe drought stress caused emissions to increase on a time scale of days. During recovery no relationship between Θ and the emissions was observed. Hence, impacts of heavy rainfall after a long lasting drought cannot be described by this approach.

FLUXES OF OZONE AND ISOPRENE IN A POPLAR PLANTATION FOR BIOENERGY PRODUCTION

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The need for renewable energy sources to meet EU Directive 2009/28/EC will lead to a considerable expansion in the planting of dedicated fast-growing biomass crops managed as short rotation coppice (SRC) across Europe. In this study we report a field campaign where the exchange of biogenic volatile organic compounds (VOC), CO_2 water vapor and ozone (O_3) was monitored using the eddy covariance technique during an entire growing season (June - November 2012) above a poplar (*Populus*) SRC plantation located in Lochristi (East-Flanders, Belgium). Our results confirmed that isoprene and methanol were the most abundant fluxes emitted, accounting for more than 90% of the total carbon released in the form of VOC. Isoprene and methanol fluxes mainly occurred on the hottest days under high light intensities when also net carbon uptake and evapotranspiration reached the highest rates. The highest isoprene emissions were observed when leaf area index was highest. O_3 fluxes were dominated by the stomatal uptake and showed a well-defined trend that matched the diurnal trend of the isoprene and methanol emissions. The field campaign was characterized by a remarkable peak of isoprene emission that corresponded to a peak of O_3 uptake by the canopy and to high concentrations in the air. The deposition velocity and canopy conductance did not show significant variations during the same period. Future research will focus on the application of models to predict the impact of VOC emissions on O_3 formation by considering the basal isoprene emission rate during the day not constant.

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Keywords: Ozone, VOCs emission, bioenergy crops, air pollution, short rotation forestry