

**ICP Forests**  
**today's evaluations and future monitoring**

Abstracts of the

**2<sup>nd</sup> ICP Forests Scientific Conference - 2013**  
28/29 May 2013, Belgrade, Serbia.





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ICP Forests Conference 2013

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## **The Conference**

The 2<sup>nd</sup> ICP Forests Scientific Conference addresses scientists within and beyond the ICP Forests community, their partners and respective stakeholders, as well as interested scientists and experts from National Forest Inventories and other related fields, such as biodiversity, global change, forest health and air pollution effects on forests. Since 1985, the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) operating under the UNECE Convention on Long-range Transboundary Air Pollution has collected data on forest condition (health, growth, diversity, nutrition) and environmental factors (air chemistry, deposition chemistry, soil and soil solution chemistry, tree chemistry, meteorology) across Europe. The data are today used by a wide range of scientists working on different ecological research questions.

This conference aims to provide an overview on latest ICP Forests results in policy relevant fields like air pollution and climate change effects on Europe's forests, as well as biogeochemical cycling, biodiversity and forest health and to focus on future forest monitoring perspectives. It intends to offer a broad platform for scientists working on similar data sets and topics to discuss scientific questions and share experiences. The conference links monitoring experts, researchers and modelers. Data users benefit from background information related to the data sets. Data providers profit from an advanced insight into the latest statistical applications based on their data.

### **Scientific Committee:**

Marco Ferretti (TerraData environmetrics, Italy, chair)

Bruno De Vos (INBO, Belgium)

Richard Fischer (TI, Hamburg, Germany)

Karin Hansen (IVL, Sweden)

Marcus Schaub (WSL, Switzerland).

## Agenda

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8.00 – 9.00	Registration	Mounting of posters
9.00 – 9.25	Opening	

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### 9.25-12.30: Session 1. The biological response of forests to environmental factors.

**Chair: Karin Hansen**

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9.25 – 9.45	K. Percy	Keynote: Requirements for future forest monitoring – a case study from the oil sands region, Alberta, Canada
9.45 – 10.00	S. Orlović et al.	Keynote: Forest monitoring and ecosystem research in Serbia (summary of several abstracts)
15 min	S.D. Veresoglou et al.	A test of the nitrogen disease hypothesis for European forests.
15 min	M. Ferretti et al.	Defoliation and nitrogen deposition in Europe: a study on four tree species within the ICP Forests network

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**10.30 – 11.00 Coffee**

### 11.00 – 12.15: Session 1 continued

**Chair: Richard Fischer**

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15 min	A. De Marco et al.	What are the most important parameters affecting crown defoliation in European forests?
15 min	A. Griffiths and N. Augustin	Spatio-temporal modelling of crown condition data
15 min	L. Suz and M. Bidartondo	Mycorrhizas of European forests: belowground indicators and their environmental drivers
15 min	M. Schaub et al.	Twelve years of ozone and ozone effects monitoring in European forests – a critical review
5 min	S. Etzold et al.	Analysing the impact of atmospheric deposition and climate change on forest growth in European monitoring plots

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**12.15 – 13.15 Lunch**

### **13.15 – 14.45 Session 2. Factors driving the biological response.**

**Chair: Marcus Schaub**

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15 min	N. Cools et al.	A harmonised soil database to understand processes and changes in forest condition in Europe
15 min	E. Graf Panattier et al.	Review of temporal changes in soil solution chemistry over the past 20 years across Europe
15 min	M. Camino Serrano et al.	Factors controlling spatial variability of DOC concentrations in soil solution at European level
15 min	P. Waldner et al.	The contribution of stemflow to total deposition
15 min	B. Ahrends et al.	The impact of canopy structure on the spatial variability of the dry deposition
15 min	K. Hansen et al.	Seasonality in Na/Cl molar ratios in precipitation and throughfall samples
5 min	D. Zlindra et al.	Do throughfall sampler size and shape matter in deposition measurements – a comparison between harmonized and national samplers

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### **15.00- 16.30 Session 3. Poster session.**

**Chair: Bruno De Vos**

15.00 – 15.30 Poster presentations (1 slide, 1 min per poster)

### **15.30 – 16.30 Posters and Coffee**

### **16.30 – 17.30 Session 4. New tools, new ideas, new perspectives. Summing-up.**

**Chair: Marco Ferretti**

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5 min	C. Lavanchy et al.	Estimating leaf area index in coniferous forests in Switzerland using LIDAR
5 min	E. Gottardini et al.	The Level I network: forests and beyond – the Ozone EFFORT study in Trentino (Italy)
5 min	M. Schaub et al.	Assessment of ozone flux for Swiss Level II plots; application – validation – further development
5 min	V. Mues and K. Olschofsky	FORMIT simulation study on CO <sub>2</sub> mitigation potential in European forests by forest management strategies
20 min	Discussion and conclusions	
10 min	K. Percy	Book presentation event: Ferretti and Fischer – Forest Monitoring

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### **17.30 Closing**





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## **The impact of canopy structure on the spatial variability of the dry deposition**

*Bernd Ahrends<sup>1</sup>, Henning Meesenburg<sup>1</sup> & Karin Hansen<sup>2</sup>*

<sup>1</sup> Northwest German Forest Research Station, Germany, bernd.ahrends@nw-fva.de,

<sup>2</sup> IVL Swedish Environmental Research Institute, Sweden,

An important nutrient input to forest ecosystems occurs through deposition. Thus, the prediction and regionalization of deposition is of fundamental importance for forest management and environmental policy. The total deposition of base cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ) is often estimated using the canopy budget method where the dry deposition factor (DDF) is a prerequisite for the calculations. The most influencing stand parameters affecting DDF to forests need to be quantified in order to assess the impact of forest management on total deposition and to regionalize deposition using forest inventory data. Generally, dry deposition to the canopy is related to atmospheric turbulence. A range of canopy and stand structure parameters affect the atmospheric turbulence. These are mainly canopy closure, stand and single tree height, leaf area index (LAI), frontal area index (FAI), crown density and volume. For practical applications models relating deposition to the above canopy structure parameters should mainly require easy-available forest inventory data and meteorological parameters like precipitation or annual sum of wet deposition.

The objectives of this study are to (1) identify the most important structure variables for deposition using mix-effect models, (2) study the effect of tree species on deposition, (3) assess the impact of stand and canopy structure on the spatial variability of deposition to the forest, (4) evaluate the suitability of stand information for regionalization of deposition.

The impact of canopy structure on the spatial variability of deposition can best be tested for sites where continuous measurements of throughfall are available, and where the main forest structure characteristics (height, diameter at breast height, density, LAI) are measured. We used annual throughfall deposition measurements conducted under different site and stand conditions from ICP Forests Level II Intensive Monitoring plots in order to test the transferability of the developed functions. Mixed effect models are used for model development taking the “pseudo-replicated” deposition and stand data at every single monitoring site into account. We will present results of our analysis as well as the validation with a completely independent data set.

## **Daily dynamics of photosynthetic parameters in beech (*Fagus sylvatica* L.) mountain population in relation to environmental conditions**

*Milan Borišev, Rita Horak, Slobodanka Pajević, Nataša Nikolić, Milan Župunski*

University of Novi Sad, Faculty of Sciences, Serbia, milan.borisev@dbe.uns.ac.rs

Monitoring of mountain forest ecosystems in specific humidity and temperature conditions is of high importance. Effects of temperature, soil and air humidity on the physiological parameters of beech were measured during the peak of vegetation period (July, August, September, 2012). The investigated forest population was located near the Fruška gora mountain peak, where the water runs off quickly and consequently, very often drought develops. The net photosynthetic rate, transpiration and water use efficiency (WUE) were measured in every hour per day. The concentrations of photosynthetic pigments, soil water capacity, number and size of stoma were measured once a month. Decreasing trend of photosynthesis during the growing season was obvious. Diurnally photosynthesis of beech leaves showed rhythmical changes. It was the most intensive in the morning (around 9 am), then decreased between noon and 1 pm, and again increased during early afternoon. This dynamics could be explained with significant correlation between photosynthesis and weather conditions: high temperature and the following water deficit cause decreasing trend in photosynthesis. This is also explanation for transpiration rate and WUE decreasing trend during growing season and senescence. There was not significant correlation between the content of photosynthetic pigments and photosynthesis, because there had not been signs of leaves senescence. Although, soil water capacity did not show significant decreasing trend from July to September, decline in photosynthesis and transpiration suggested adaptation of beech plants to drought and high temperature stress conditions. Therefore, monitoring of physiological parameters could be important for defining forest ecological conditions. Physiological status, primary photosynthetic productivity of forests, could be significant indicator of environmental conditions and climate changes.

## Estimate of growth loss by ozone for Swiss forests based of flux models

Sabine Braun<sup>1</sup>, Beat Rihm<sup>2</sup>, Christian Schindler<sup>3</sup>

<sup>1</sup> Institute for Applied Biology, Schönenbuch, Switzerland, sabine.braun@iap.ch,

<sup>2</sup> Meteotest, Berne, Switzerland

<sup>3</sup> Swiss Tropical and Public Health Institute, University of Basel, Switzerland

Air pollution abatement measures during the last 25 years have led to a decrease of peak concentrations of ground level ozone in Europe (Protocols to the Convention on long-range transboundary air pollution; 1988: Nitrous oxide protocol; 1999: Gothenburg protocol<sup>1</sup>). However, climate change will enhance ozone formation due to increased radiation and may thus result in rising average ozone concentration.

The effect of ozone on tree growth has been well examined in a number of open-top chamber experiments with young trees. A recent re-evaluation of these experiments using ozone uptake rather than external concentration has led to a new dose-response relationship and to the establishment of a flux based critical level (Mills et al. 2011). However, the extrapolation of growth results from young trees to mature forests is difficult and needs validation. The fumigation experiments with mature trees in Kranzberg (Matyssek et al. 2010) suggested that the ozone sensitivity of mature trees is at least similar or even greater than of young trees. However, such experiments cannot be run in large scale. The epidemiological analysis of growth from forest trees along measured/modelled ozone data may be an alternative. They need, however, good information on other environmental data for the sites which may confound the relation between ozone and growth such as soil water availability.

Such a data analysis was made in Switzerland for stem increment of beech (*Fagus sylvatica*, L.) in 68 observation plots over 4 increment periods of 4 years each (60 trees per plot). Ozone flux was calculated for 23 rural monitoring stations using the uptake model DO3SE (Büker et al. 2011) and then mapped to get annual estimates for each observation plot. Soil water was modelled for each site using a hydrological model (Schulla and Jasper 2007) based on soil profile data. The results confirm the dose-response relationship obtained from the open top chamber experiments. From the mapped ozone flux, the national forest inventory (NFI/WSL 1992) and the dose-response relationship the growth reduction by ozone in deciduous forests is estimated to be at 13.5% on the national scale.

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<sup>1</sup> Protocol to the 1979 Convention on long-range transboundary air pollution to abate acidification, eutrophication and ground-level ozone. <http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/1999%20Multi.E.Amended.2005.pdf>

## **Can data from ozone passive samplers and daily meteorological means be used for calculating ozone fluxes?**

*Vicent Calatayud<sup>1</sup>, Alessandra De Marco<sup>2</sup>, Pierre Sicard<sup>3</sup>, Elena Paoletti<sup>4</sup>, Esperanza Calvo<sup>1</sup>, Marcus Schaub<sup>5</sup>*

<sup>1</sup> Fundación CEAM (Spain) vicent@ceam.es,

<sup>2</sup> ENEA Cassacia (Italy),

<sup>3</sup> ACRI-ST (France),

<sup>4</sup> IPP-CNR (Italy),

<sup>5</sup> WSL (Switzerland),

Tropospheric ozone is an air pollutant of major concern for vegetation. To protect plants from adverse effects under the respective microclimatic and physiological conditions, new flux-based critical levels have been established (e.g., ICP Modelling and Mapping, 2004). However, the assessment of ozone flux is very data intensive and may pose a serious limitation. One major challenge for forest sites is the fact that ozone concentrations are often measured with passive samplers, typically providing mean ozone concentrations over a period of two weeks. Another restriction is that meteorological data are usually available as daily means whereas currently used ozone flux calculation routines of DO<sub>3</sub>SE require hourly values for ozone concentration and meteorological parameters.

In an ongoing study, active monitors and modelled ozone data from France, Italy, Spain and Switzerland are being used to test an alternative approach using weekly to monthly mean values for ozone concentrations and daily means for meteorological parameters to assess ozone fluxes. A study by Calatayud (2013) used data from several Spanish air quality stations and provided promising results. In this study, we aim to testing the applied alternative approach for a wider territory and a larger number of sites.

This study provides a valuable contribution towards the flux-based ozone risk assessment for forests as this method may allow calculating ozone fluxes based on passive sampler measurements and daily meteorological data at remote forests sites such as level II ICP Forest plots.

### **References**

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- ICP Modelling and Mapping (2004). ICP Modelling and Mapping, Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends, Federal Environmental Agency (Umweltbundesamt), Berlin (2004) <[www.icpmapping.org](http://www.icpmapping.org)> UBA-Texte 52/04.



## **Factors controlling spatial variability of DOC concentrations in soil solution at European level**

*Marta Camino Serrano<sup>1</sup>, Ivan Janssens<sup>1</sup>, Sebastiaan Luysaert<sup>2</sup>, Bert Gielen<sup>1</sup>, Bertrand Guenet<sup>1</sup>, Bruno De Vos<sup>3</sup>, Nathalie Cools<sup>3</sup>, Philippe Ciais<sup>2</sup>*

<sup>1</sup> University of Antwerp, Belgium, marta.caminoserrano@ua.ac.be;

<sup>2</sup> Laboratoire des Sciences du Climat et de l'Environnement, France,

<sup>3</sup> Research Institute for Nature and Forest (INBO), Belgium,

The lateral transport of dissolved organic carbon (DOC) is an important and not well-understood process linking terrestrial and aquatic ecosystems. To date, very few Earth System Models (ESMs) represent explicitly this process despite its crucial role in the global carbon cycle. More accurate information is needed in order to be able to predict DOC dynamics. Within this framework, a database was designed to compile data on DOC concentrations in soil solution at different depths with special focus on European sites. The database contains information on 349 sites, with 304 being forest. The majority of the data was provided by International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). The database also includes other meta-data, such as vegetation type, soil properties, climate and other soil solution parameters.

The analysis of the database focuses on: 1) the study of the environmental and physical factors that are acting as drivers of [DOC] changes in soil solution across sites at European level, and 2) the DOC distribution through the soil profile and how this varies with different vegetation types and soil properties. The preliminary results show that variables related to biological processes (NDVI in summer or litter decomposability) are important in explaining the spatial distribution of the [DOC] in soil solution at surface layers, while other variables such as iron or aluminum in soil and soil solution become more important in explaining DOC variability in subsoil. With regards to the vertical profile of DOC, we found that there is a pronounced decrease of [DOC] with depth in forests with specific patterns for broadleaved and coniferous forests.

The relationships achieved will shed light on the most important drivers of [DOC] variability, and can therefore help in the design, parameterization and validation of current and future DOC models.

## **A harmonised soil database to understand processes and changes in forest condition in Europe**

*Nathalie Cools<sup>1</sup>, Bruno De Vos<sup>2</sup>, Richard Fischer<sup>3</sup>*

<sup>1</sup> INBO, Research Institute for Nature and Forest, Belgium, [nathalie.cools@inbo.be](mailto:nathalie.cools@inbo.be),

<sup>2</sup> INBO, Research Institute for Nature and Forest, Belgium,

<sup>3</sup> Thünen Institute for World Forestry, PCC of ICP Forests, Germany

Trend analysis in long-term forest monitoring look for explaining variables which can possibly be found in the soil condition. The soil plays a role in input-output budget modelling and critical load calculations take into account a high number of chemical and physical soil characteristics. Soil data are also necessary to calibrate and validate models that predict future impacts.

In the nineties a first forest soil condition survey was conducted on nearly 800 ICP Forests intensive monitoring plots across Europe. Although a large number of plots were included, the dataset was fully not harmonised. Neither much attention was given to physical soil variables - such as bulk density or content of coarse fragments (De Vries et al., 1998). In the meantime the main focus of environmental forest research changed and moved from air pollution to climate change effects. During the EC Forest Focus BioSoil demonstration project and the Life+ FutMon programme, the opportunity was provided to include a number of the ICP Forests intensive monitoring plots in the large-scale forest soil inventory following the methods as outlined in the ICP Forests manual on sampling and analysis of soil (Cools and De Vos, 2010).

The current database contains a comprehensive set of harmonised and validated recent soil data (from 2003 onwards) on 274 intensive monitoring plots across Europe. Data have been aggregated by fixed depths layers. The importance and relevance of this dataset lays also in the fact that a high number of other forest ecosystem surveys are combined - for a long term - on these plots. There is a good overlap with crown condition, foliar, deposition, meteorological, soil solution and growth surveys. Further, the results obtained on these intensive monitoring plots can be upscaled to the systematic 16 x 16 km grid across Europe by means of the Level I soil inventory.

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- Cools, N., De Vos, B. 2010. Sampling and Analysis of Soil. Manual Part X, 208 pp. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, UNECE, ICP Forests, Hamburg. ISBN: 978-3-926301-03-1. [<http://icp-forests.net/page/icp-forests-manual>]

## What are the most important parameters affecting crown defoliation in European forests?

Alessandra De Marco<sup>1</sup>, Chiara Proietti<sup>2</sup>, Irene Cionni<sup>1</sup>, Tamara Jakovljevic<sup>3</sup>, Richard Fischer<sup>4</sup>,  
Marcello Vitale<sup>2</sup>

<sup>1</sup> ENEA, CR Casaccia, Rome, Italy, alessandra.demarco@enea.it,

<sup>2</sup> University of Rome, Italy,

<sup>3</sup> Croatian Forest Research Institute, Croatia,

<sup>4</sup> Thünen Institute for World Forestry, Hamburg, Germany

Defoliation is one of the forest health parameters monitored by the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). Moreover, crown defoliation may be caused by a number of biotic and abiotic stressors. Defoliation assessment attempts to quantify foliage missing as an effect of stressors including air pollutants. Changes in defoliation attributable to air pollution cannot be differentiated from those caused by other factors. An epidemiological study on defoliation in Europe has to take in account not only air pollution parameters but also other environmental stresses. Critical Loads, "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge", and their exceedances, are one of the more discussed environmental stress factors. An epidemiological study has been carried out looking at the impacts of environmental stressors, including meteorological variables, nitrogen deposition, nutrient nitrogen critical loads and their exceedances, on crown defoliation of European forests in the years 2001, 2006 and 2011. The study was implemented through an integrated approach based on Random Forest Analysis (RFA), and multiple regression modelling, because no linear correlations between defoliation and environmental stressors were found. The analysis was performed for 2001 and 2006, and the year 2011 was used as cross validation. Crown defoliation appears to be mainly related to meteorological variables in *P. abies*, whereas in *F. sylvatica* and *Q. ilex* it is more related to other predictors linked to air pollution, such as nitrogen deposition. Whilst crown defoliation is well predicted for *Q. ilex* by linear multiple regression with low predictors number derived by the RFA, likelihood values were lower for *F. sylvatica* and *P. abies*, suggesting that linear models can't predict the crown defoliation observed in 2011.

## Impact of some harmful factors on results of tree crown condition assessment in Vojvodina

Milan Drekić, Verica Vasić, Leopold Poljaković - Pajnik, Predrag Pap, Andrej Pilipović, Saša Orlović

University of Novi Sad, Institute of Lowland Forestry and Environment, Serbia, mdrekic@uns.ac.rs

Forest ecosystems are severely endangered by the effect of detrimental factors. There are many risk factors and they can be divided into abiotic (drought, early and late frost, high temperature, etc.), biotic (insect pests, plant disease agents, etc.) and anthropogenic factors, resulting from human activities (direct adverse effects, air pollution, climate changes, etc.). At the end of 1980's in Serbia was established network of ICP Level 1 monitoring plots which was reconstructed in the period 2003-2004. In the network of Level 1 ICP monitoring plots, 13 plots is located on the territory of Autonomous Province of Vojvodina and managed by Institute of Lowland Forestry and Environment where monitoring of crown condition is performed continuously.

This paper presents the analysis of the results of assessment of crown conditions on 13 Level 1 sample plots and impact of some of harmful factors on crowns condition of most common tree species such are: (I) sessile oak, (II) pedunculate oak, (III), black locust, (IV) euramerican poplar, (V) Austrian pine and (VI) Turkish oak in the period of 2004 – 2012 in Vojvodina. The continuous work on forest condition monitoring is performed annually during the full vegetation of forest trees (July and August) and includes the assessment of tree crown condition. A basic element for assessment of condition of tree crowns is defoliation of the assimilation organs. Total defoliation of crowns was determined by the classes of defoliation according to ICP Forests Manual. Besides manual, assessments of impact of biotic and abiotic damage factors were classified into 5% classes.

Analysis of the results showed that the highest degrees of damage were identified on pedunculate oak and Austrian pine trees. The results of forest condition monitoring on sample plots indicate high effect of drought and harmful biotic factors (insects, disease agents) on crown defoliation degree. The significant damage of the foliage mass of different tree species was caused by insects: *Parectopa robinella* Clemens, *Phyllonorycter robiniae* Clemens, and by early season defoliators (fam. Tortricidae, fam. Geometridae). The crown condition was also affected by the infestation of the phytopathogenic fungi *Marssonina brunnea* (Ell. & Ev.) P. Magn., *Microsphaera alphidoides* Griff. et Maubl., *Diplodia pinea* Dasmaz., and *Dothistoma pini* Hulbary.

## **Quality assurance for the forest condition survey in Germany – Results of the national training courses from 1992 to 2012**

*Nadine Eickenscheidt and Nicole Wellbrock*

Thünen Institute of Forest Ecosystems, Alfred-Möller-Strasse 1, 16225 Eberswalde, Germany

The federal states are responsible for the field assessment of the forest condition survey in Germany whereas the evaluation of the forest condition for Germany is carried out by the Thünen Institute and the results are finally published by the Federal Ministry for Food, Agriculture and Consumer Protection. Reliability (consistency and reproducibility) of the visually assessed defoliation data within Germany is of prime importance for the forest condition survey. Thus, annual national training courses were introduced as one major quality assurance procedure. The participating observer teams at the training courses consist of at least one representative who conducts the forest condition survey or who is responsible for the training course in its respective federal state. Hence, we focus on the reliability of the visual assessed defoliation data from the training courses between 1992 and 2012. Defoliation estimations were carried out in beech (*Fagus sylvatica*), oak (*Quercus robur* and *Quercus petraea*), Norway spruce (*Picea abies*), and pine (*Pinus sylvestris*) stands. On average, 94% of the defoliation estimations were located within the  $\pm 10\%$  interval of deviation regarding all years. The mean absolute deviation was  $\pm 4.4\%$  defoliation and the deviation depended non-linearly on the level of defoliation with highest deviations at intermediate defoliations. A trend towards increasing harmonisation was observed from 1992 to 2012, in particular for oak and spruce. In spite of high correlations and agreements among observers, systematic errors were detected. However, pronounced outliers could be explained in most cases and the observed error was frequently irrelevant for the national forest surveys. The present study demonstrated that in recent years the defoliation assessment at the national training courses produce reliable data within Germany.

## **Analysing the impact of atmospheric deposition and climate change on forest growth in European monitoring plots**

*Sophia Etzold<sup>1</sup>, Gertjan Reinds<sup>2</sup>, Svein Solberg<sup>3</sup>, Peter Waldner<sup>1</sup>, Marcus Schaub<sup>1</sup>, Wim de Vries<sup>2</sup>*

<sup>1</sup> Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland, sophia.etzold@wsl.ch

<sup>2</sup> Alterra, The Netherlands

<sup>3</sup> Norwegian Forest and Landscape Institute, Norway,

Aim of this study is to undertake an integrated analysis of 15 years (1995 to 2010) of growth and deposition data to derive widely applicable quantitative relationships between N, S and O<sub>3</sub> exposure (POD) and ecosystem carbon balance, accounting for differences in climatic conditions.

Growth data of 349 even-aged ICP Forests level II plots across Europe, dominated by beech, oak, spruce and pine trees were jointly analyzed with meteorological and deposition data derived from the Climatic Research Unit dataset and EMEP database, respectively. The expected increment value before major anthropogenic influences was assessed for all plots based on site productivity curves, age and stand density index, and relative growth was expressed as percentage ratio of actual growth against expected growth.

In general, relative forest increment was non-linearly related to nitrogen deposition with a fertilizing effect of nitrogen on growth up to a threshold of c. 30 kg ha<sup>-1</sup> y<sup>-1</sup> of N. For higher nitrogen levels declining increment could be observed. For low-nutrient sites the fertilizing effect of N on growth was more than double. Differentiating the plots by species, only spruce and pine forests exhibited a significant relationship of increment against N deposition.

For coniferous forests, the impact of POD on forest growth was masked by the fertilizing effect of nitrogen, as POD and nitrogen were positively correlated. Deciduous forests exhibited generally higher POD values compared to coniferous forests. The question arises whether POD might inhibit the fertilizing effect of N in deciduous forests.

Further, the impact of deposition on forest increment during three inventory periods with differing climatic conditions will be discussed.

## **Reduced growth on defoliated trees – evidence from the RENECOFOR plots, France**

*Marco Ferretti<sup>1</sup> and Manuel Nicolas<sup>2</sup> on behalf of the ONF and TerraData project teams*

<sup>1</sup>TerraData environmetrics, Via L.Bardelloni 19, 58025, Monterotondo Marittimo (Gr), Italy, ferretti@terradata.it

<sup>2</sup>Département Recherche et Développement, Direction Technique et Commerciale Bois, Office National des Forêts, Boulevard de Constance, 77300, Fontainebleau, France

The impact of defoliation on tree growth at the plots of the French Level II network RENECOFOR was examined for two growing periods: 1995-2004 (47 plots, 2008 trees) and 2000-2009 (63 plots, 3116 trees). Trees were assessed annually for defoliation and measured periodically for circumference. Circumference data were transformed into periodical (10 years) basal area increment (BAI). The study considered both (i) direction and significance of defoliation-growth and (ii) occurrence, size and significance of BAI deviation of defoliated trees (>10%) with respect to the BAI of undefoliated ( $\leq 10\%$ ) trees (relative BAI).

The periodical BAI resulted negatively and significantly related to defoliation: the higher the defoliation, the lower the BAI. This was demonstrated true for both the investigated growth periods, and was confirmed by the meta-analysis of individual plot results. A statistically significant reduction of median relative BAI of defoliated trees (defoliation >10%) with respect to undefoliated trees (defoliation  $\leq 10\%$ ) was detected. Defoliation threshold for such a significant reduction ranges more frequently between 15 and 25%. Some considerable differences may occur with respect to tree species. A generalized, distinct, continuous and significant reduction of relative BAI was obvious even at very low defoliation level, and a relative BAI reduction of 1.17-1.49% per unit increase of defoliation can be expected for conifers, and 0.73% for broadleaves. These results are consistent with early findings by Söderberg (1993), Solberg (1999) and Solberg and Tveite (2000). Hence defoliation can be arguably considered as an effective indicator of a factor (forest health) that may impact forest management in economical and ecological terms. Besides opening new research and investigation questions, in our opinion the results provided a strong argument for the maintenance of the monitoring network.

## **Defoliation and nitrogen deposition in Europe: a study on four tree species within the ICP Forests network**

*Marco Ferretti<sup>1</sup>, Marco Calderisi<sup>1</sup>, Aldo Marchetto<sup>2</sup>, Peter Waldner<sup>3</sup>*

<sup>1</sup>TerraData Environmetrics, Italy, ferretti@terradata.it

<sup>2</sup>National Research Council, Institute of Ecosystem Study, Italy, a.marchetto@ise.cnr.it

<sup>3</sup>Swiss Federal Research Institute WSL, Switzerland, peter.waldner@wsl.ch

We present a first attempt to analyze data from long-term, coupled monitoring of N deposition, tree nutrition, health and growth collected at the intensive monitoring plots of the ICP Forests in order to investigate whether N deposition have some role in explaining the defoliation of four main tree species in Europe: beech (21 plots), pedunculate oak (10 plots), scot pine (23 plots) and Norway spruce (28 plots).

Partial Least Square Regression (PLS), a regression technique that generalises and combines features from principal component analysis and multiple regression, was used to predict a set of dependent variables from a large set of predictors.

Geographical (latitude, longitude and elevation), meteorological (total and summer precipitation) and stand (tree density) variables were used for the null (reference) model. Three other models were tested adding tree damage, N deposition and tree damage+N deposition, respectively.

According to the species and the variables considered, the PLS regression models were able to account for 6.8 to 73.1% of the variance of observed defoliation. Longitude, precipitation and tree density were the key variables in the null models, with different reported actions, according to the species. Damage was the variable with the highest potential in terms of improvement of model performance with respect to the null model: when significant, it was always positively related to defoliation. N Flux was also proven to improve the null model for beech (but not or slightly for the other species), and – when significant – also with positive relationship with defoliation. The combined addition of N Flux and damage improved the beech and Scot pine model. In synthesis, while damage was proven to be a consistent and important variable for all species, a distinct, substantial role for N was obvious only for beech.



## **The Level I network: forests and beyond – the Ozone EFFORT study in Trentino (Italy)**

*Elena Gottardini<sup>1</sup>, Fabiana Cristofolini<sup>1</sup>, Antonella Cristofori<sup>1</sup>, Marco Ferretti<sup>2</sup>*

<sup>1</sup> IASMA Research and Innovation Centre, Fondazione Edmund Mach, Via E. Mach 1, 38010 San Michele all'Adige (TN), Italy, elena.gottardini@fmach.it, fabiana.crostofolini@fmach.it, antonella.cristofori@fmach.it

<sup>2</sup> TerraData environmetrics, via L. Bardelloni 19, 58025 Monterotondo M.mo, Grosseto, Italy, ferretti@terradata.it

Traditionally, Level I forest monitoring network has been used for assessing status and trends of forest condition. Here, we demonstrate its potential in providing a framework for cause-effect relationships and risk analysis, even at local level and beyond the forest community. We considered ozone as a key environmental factor.

The 15 Level I plots in the Trento province (Northern Italy) were equipped with passive samplers for ozone, and data were used for three main studies: (i) evaluation and mapping of potential risk for forests; (ii) cause-effect investigation in terms of ozone impacts on defoliation and growth; (iii) evaluation and mapping of ozone risk for human population. All the three studies were based on five years of measurements.

As for study (i), passive sampling data were used for geo-statistical modelling. Results show that ozone critical levels were exceeded over wide areas with approximately 71 % of forests in Trentino exposed at AOT40 values higher than two times the UNECE Critical Level.

Despite these results, the study (ii), based on Linear Mixed Models and Multiple Regression, suggested that ozone has a limited (if any) impact on defoliation and growth, in terms of relative Basal Area Increment (BAI) as measured on Level I plots. These results were confirmed by a time series analysis carried out on one Level II plot, and also when considering the flux approach.

Finally (iii), data originated from Level I passive sampling, integrated with other available measurements (ozone concentrations from automatic analysers, population census) allowed for mapping the risk of potentially dangerous ozone exposure for human population.

All together the results provide evidence that the Level I network can be useful much beyond its traditional, intended aim, and – with a few integration initiatives - can be a suitable framework to address a wide range of environmental concerns, even at local level.

## **Review of temporal changes in soil solution chemistry over the past 20 years across Europe**

*Graf Pannatier E.<sup>1</sup>, Clarke N.<sup>2</sup>, Cools N.<sup>3</sup>, Hansen K.<sup>4,5</sup>, Jonard M.<sup>6</sup>, Klinck U.<sup>7</sup>, Meesenburg H.<sup>7</sup>, Nicolas M.<sup>8</sup>, Nieminen T.<sup>9</sup>, Vanguelova E.<sup>10</sup>, Verstraeten, A.<sup>3</sup>, Vesterdal L.<sup>5</sup>, Vilhar U.<sup>11</sup>*

<sup>1</sup> WSL, Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland, elisabeth.pannatier@wsl.ch

<sup>2</sup> Norwegian Forest and Landscape Institute, Norway

<sup>3</sup> INBO, Research Institute for Nature and Forest, Belgium

<sup>4</sup> IVL Swedish Environmental Research Institute, Sweden

<sup>5</sup> Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark

<sup>6</sup> UCL, Université catholique de Louvain, Earth and Life Institute, Belgium

<sup>7</sup> Northwest German Forest Research Station, Germany

<sup>8</sup> Office National des Forêts, Département R&D, France

<sup>9</sup> Metla, Finnish Forest Research Institute, Finland

<sup>10</sup> Centre for Forestry and Climate Change, United Kingdom

<sup>11</sup> Slovenian Forestry Institute, Slovenia

Soil solution chemistry is a valuable indicator to assess soil nutrient availability and the impact of air pollution and other stress factors on forest soils and ecosystems. Soil solution has been monitored in 353 Level II plots of the ICP Forests network between 1990 and 2010. The temporal analysis of the long-term measurements allows us to assess the responses of the soil solution, and indirectly of the soil, to the air pollution abatement that has occurred since the mid-1980s across large parts of Europe.

Several studies investigating the temporal changes in soil solution chemistry over the past decades at regional or national scale have recently been published. They show that soil solution has reacted differently to atmospheric pollution and that other factors (e.g. drought, storm, forest management, sea-salt episodes) have changed their composition for more or less long periods.

Before we start a pan-European temporal analysis of the soil solution chemistry using ICP Forests data, we aim to review published studies to identify the main responses of the soil solution and the explanatory factors for these changes. This review allows us to establish a range of responses typically explained by certain processes (e.g. sulphate adsorption/desorption, cation exchange) or events (e.g. tree harvesting, felling). Based on this typology derived from a “case study” approach, we select the adequate statistical methods (e.g. seasonal Mann-Kendall test, spectral analysis, temporal semi-variogram, linear mixed models) to search for patterns in changes (seasonal or long term cycles, events, monotonic trends) in the soil solution chemistry across Europe.

This presentation presents the different temporal patterns of soil solution chemistry and the recommendations for statistical tools to be applied to a time series analysis of soil solution data.

## **Spatio-temporal modelling of crown condition data**

*Alex Griffiths and Nicole Augustin*

Department of Mathematical Sciences, University of Bath, UK, aeg32@bath.ac.uk

Data on crown condition have been collected from Level I plots of the ICP Forests monitoring system for many years. Analysing these data to assess spatial and temporal trends presents various statistical problems, particularly when we are interested in using measurements of individual trees rather than plot-level summaries. We focus here on finding an appropriate statistical distribution to model crown condition (categorised into >0-5% defoliation, >5-10% defoliation, etc, with additional classes for 0% defoliation and 100% defoliation (dead)). Such a distribution needs to allow for the bimodality (sometimes trimodality) observed in the data, with inflated values at either end of the range (perfectly healthy/completely defoliated). We present results from a zero-and-one-inflated beta regression model.

## Microbial activity in forest soil under beech, spruce, Douglas fir and fir

*Timea Hajnal-Jafari<sup>1</sup>, Mirjana Jarak<sup>1</sup>, Verica Vasić<sup>2</sup>*

<sup>1</sup> Faculty of Agriculture, University of Novi Sad, Serbia, mikrobiologija@polj.uns.ac.rs,

<sup>2</sup> Institute of Lowland Forestry and Environment, Novi Sad, Serbia

The aim of this research was to investigate the microbial activity in forest soil from different sites under deciduous and coniferous trees in Serbia. One site on Stara planina was under beech trees (*Fagus* sp.) while another under mixture of spruce (*Picea* sp.) and Douglas fir (*Pseudotsuga* sp.). The site on Kopaonik was under mixture of beech (*Fagus* sp.) and spruce (*Picea* sp.) trees. The site on Tara was dominantly under fir (*Abies* sp.), beech (*Fagus* sp.) and spruce (*Picea* sp.). Soil samples were collected from the depth of 0-30 cm after the removal of litter in June and August of 2012. The activities of dehydrogenase and  $\beta$ -glucosidase enzymes were measured by spectrophotometric methods. The total number of bacteria, the number of actinomycetes, fungi and microorganisms involved in N and C cycles were determined using standard method of agar plates. The microbial activity was affected by tree species and sampling time. The highest dehydrogenase activity, total number of bacteria, number of actinomycetes, aminoheterotrophs, amylolytic and cellulolytic microorganisms were determined in soil under beech trees. The highest total number of fungi and number of pectinolytic microorganisms were determined in soil under spruce and Douglas fir trees. Microbial activity on Kopaonik and Tara sites were few times lower in comparison with both sites on Stara planina. The activity of  $\beta$ -glucosidase enzyme was higher in June in comparison with its activity in August. The dehydrogenase activity was higher in August under beech trees. On other sites under dominantly evergreen coniferous trees, the activity of this enzyme was significantly lower. The total number of bacteria, number of actinomycetes, aminoheterotrophs and the number of bacteria from C cycle were in average higher in June. The correlation analyses proved the existence of statistically significant interdependency among investigated parameters.

## **Seasonality in Na/Cl molar ratios in precipitation and throughfall samples**

*Karin Hansen<sup>1,2</sup>, Anne Thimonier<sup>3</sup>, Peter Waldner<sup>3</sup>, Maria Schmitt<sup>3</sup>, Ülle Napa<sup>4</sup>, Lars Vesterdal<sup>2</sup>*

<sup>1</sup> IVL Swedish Environmental Research Institute, Sweden, karin.hansen@ivl.se,

<sup>2</sup> Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark,

<sup>3</sup> WSL, Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland,

<sup>4</sup> Estonian Environment Information Centre, Estonia

Solution samples of precipitation and throughfall regularly sampled in forest monitoring programs are often validated using the molar Na/Cl ratio to assure the quality of the samples. Since the sea is thought to be the largest source of sodium (Na<sup>+</sup>) and chloride (Cl<sup>-</sup>) and uptake and leaching in the tree canopy is considered negligible, the ratio in throughfall as well as precipitation samples are typically thought to be similar to that of sea salt, namely 0.86 (Keene et al., 1986). The ICP Forests Manual proposes an acceptable range in the Na/Cl ratio between 0.5 and 1.5 (Clarke et al., 2010) in order to account for other possible sources or sinks for Na<sup>+</sup> and Cl<sup>-</sup>. Samples with a ratio outside this range are recommended for reanalyzing.

Even so, deviations from the acceptable range repeatedly occur, especially in throughfall samples. Thimonier et al. (2008) evaluated the applicability of the Na/Cl ratio for Swiss conditions and found 85% of the Na/Cl ratios within the proposed range. They even noticed a clear seasonal pattern in throughfall Na/Cl ratio which they ascribed to different timing of Na<sup>+</sup> and/or Cl<sup>-</sup> canopy leaching depending largely on the tree species. This finding questions the assumption that both Na<sup>+</sup> and Cl<sup>-</sup> are inert in the forest canopy.

Based on the work of Thimonier et al. (2008) we hypothesize: i) A proportion of Na/Cl ratios in throughfall in Europe falls outside the recommended range of 0.5-1.5; ii) Leaching of Na<sup>+</sup> and Cl<sup>-</sup> from forest canopies do occur in the autumn or spring; iii) Leaching is highest from deciduous tree species. Based on these hypotheses our research questions are: i) Can Na<sup>+</sup> and Cl<sup>-</sup> be assumed inert in forest canopies? ii) Do certain tree species leach more Na<sup>+</sup> or Cl<sup>-</sup> than others? iii) Is there a different seasonal pattern in the leaching of Na<sup>+</sup> and Cl<sup>-</sup>?

We used data on precipitation, throughfall and information on tree species from ICP Forests intensive monitoring plots (in total 186 forest plots). The seasonality within the data was tested by introducing harmonic terms in a stepwise regression of the dependent variable (Na/Cl) versus time. Results from this analysis will be presented.

## **Effects of storage in field and in laboratory on temperature, light and chemistry of forest water samples**

*Karin Hansen<sup>1,2</sup>, Anne Thimonier<sup>3</sup>, Heike Fortmann<sup>4</sup>, Nils König<sup>4</sup>, Jörg Luster<sup>3</sup>, Aldo Marchetto<sup>5</sup>, Elisabeth Graf Pannatier<sup>3</sup>, Maria Schmitt<sup>3</sup>, Jeroen Staelens<sup>6</sup>, Arne Verstraeten<sup>7</sup>, Lars Vesterda<sup>2</sup>, Peter Waldner<sup>3</sup>, Daniel Žlindra<sup>8</sup>, Alois Zürcher<sup>3</sup>*

<sup>1</sup> IVL Swedish Environmental Research Institute, Sweden, karin.hansen@ivl.se,

<sup>2</sup> Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark,

<sup>3</sup> WSL, Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland,

<sup>4</sup> Northwest German Forest Research Station, Germany,

<sup>5</sup> ISE, Institute of Ecosystem Study, Italy,

<sup>6</sup> Forest & Nature Lab, Ghent University, Belgium,

<sup>7</sup> Research Institute for Nature and Forest, Belgium,

<sup>8</sup> Slovenian Forestry Institute, Slovenia

The chemical composition of solution samples can vary over time due to biological activity in the sample, exchanges and adsorption on the walls of the storage vessel, abiotic particle formation or dissolution. Factors influencing these processes include the initial composition of the sample, e.g. pH, temperature and light conditions, which directly determine the activity of microorganisms such as nitrifiers, storage duration (in the field or the laboratory), cleaning of the storage vessels, and pre-treatment of the samples before analysis (e.g. filtering, acidification).

Precipitation, throughfall and soil water regularly sampled in forest monitoring needs to be protected toward possible alterations. A range of storage experiments have been performed both in forests and in laboratories to check the quality of samples when they are stored under different conditions and situations. The first objective was to examine the change in temperature and light along with possible change in chemistry of soil solution, precipitation and throughfall samples during the period they are collected in the forest and when stockpiled in the laboratory before analysis. The second objective was to recommend methods and storage that diminish possible chemical transformations in solution samples.

Depending on the sampling design, solution samples collected in the forest were to various extents subject to ambient air temperature fluctuations during the day and high light exposure. In the summertime the temperature in samples could get unfavorably high when samples were not protected properly. Our storage experiments showed changes in chemical composition in samples stored for longer periods both in the laboratory and the forest; however, the results suggested that it is most important to reduce the duration of sampling period (i.e. weekly samples instead of bi-weekly or monthly sampling) in the forest.

## **Moss and liverworts flora in different types of beech forests in Serbia**

*Miloš Ilić, Dragana Vukov, Marko Rućando, Mirjana Krstivojević, Ružica Igić*

University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology: Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia, milos.ilic@dbe.uns.ac.rs

Mosses and liverworts play major role in ecosystem succession, productivity and decomposition, also they regulate soil climate and biogeochemical cycling. Bryophytes could be used as indicators of ecological conditions in forests, and for passive biomonitoring of heavy metals. Therefore the information on species composition and abundance of mosses and liverworts are important for valuation of forest condition and their preservation. The aim of this study was to list moss and liverworts species and to compare surveyed sites in different types of beech forests in order to determine main factors that influence the forest bryophlora. The survey was conducted during 2011 and 2012 on Tara, Kopaonik and Vidlič in different types of beech forests that are approximately at the same altitude. Studied types of forests were *Piceeto-Abieto-Fagetum* and *Piceeto-Abieto-Fageto-Alnetum mixtum* on Tara, *Fageto-Abietum* on Kopaonik and *Fagetum sylvaticae* on Vidlič Mts. One part of studied area was peatland (Crveni potok) on Tara Mts. Total number of 19 species of liverworts and 82 species of mosses was recorded. Comparison of results showed differences in species composition due to different ecological conditions caused by geographical distance and different edicator species of trees. The greatest difference was found between moss and liverworts flora of Vidlič and Tara, while the most similar sites were Tara and Kopaonik.

## **The effects of economics and natural environment in business of enterprises in sector of non wood forest products in Serbia**

*Ljiljana Keča and Milica Marčeta*

Faculty of Forestry, University of Belgrade, Serbia, ljiljana.keca@sfb.bg.ac.rs

**Keywords: non wood forest products, enterprises, Serbia, land, trends**

NTFPs are not fully involved in the economic development programs in most states, but they provide significant financial benefits for rural entrepreneurs. Raw material availability and diversity of Serbia, encourages important part, especially the rural population to focus on the collection of NTFPs in nature and their offer on the market. The quality of the soil along with other natural conditions largely determines the yield of this product group. In this sense, the research is divided into two segments. The first part is based on the identification of trends in the purchase and sale of NWFPs in Serbia with applying correlation and regression analysis. In the second part is shown a parallel view of SWOT analysis and AHP for economic social environment in which surveyed enterprises doing business and state of land resources in the other side. From this point, the aim of the research is to connect the development in the commercialization NWFPs with environmental factors. The purpose of this research is to indicate the certain measures that would contribute to the improvement of operations of NWFPs businesses according to the situation in the surveyed enterprises and their environment. However, it is pointed the possible courses of action on the land in order to improve its productivity, which would have multiple positive effects with a particular emphasis on increasing NWFPs yield. Subject of research are companies engaged in the purchase, processing and sale of NWFPs in Serbia, purchased and marketed quantities of these products, as well as secondary data Republic Statistics Office. The main applied research technique is interviews.



## Presence of invasive plant species in forest communities of Deliblato Sands

Mirjana Krstivojević, Dragana Vukov, Marko Rućando, Miloš Ilić, Ružica Igić

Department of Biology and Ecology, Faculty of Sciences, Novi Sad, mirjana.krstivojevic@dbe.uns.ac.rs

Deliblato Sands, as well as all Northern Serbia is in the climate-zonal vegetation with steppe-woods characteristics. Detailed analysis of the habitat types on Deliblato Sands showed domination of grasslands and high sedges, with a particularly distinguished open thermophilous pioneer vegetation on sandy soils and perennial grass limestone formations and basic steppe vegetation, all equally present. Spontaneous overgrowth of steppe with shrub and woody species and intensive forestation, led to the formation of different forest communities in this area. Although anthropogenic woodlands of Black Locust and pine dominate, there are also natural communities present: *Quercus-Tilietum tomentosae* L. Stjepanović-Veseličić 1953, *Rhamneto-Quercetum virgiliana* Gajić, *Convallario-Quercetum roboris* Sós 1957, *Populeto-Salicetum* Rajevski 1950.

The aim of this study is to estimate the presence of invasive plant species and their threat to the integrity and sustainability of forest ecosystems of Deliblato Sands.

Analysis included all forest communities of the surveyed area, with the emphasis on natural phytocenoses. All available data are accumulated in the database with the help of TURBOVEG software package. Within each association, species composition, participation and fidelity of adventive plants, their life forms, origin and dispersion tendencies were analyzed. The comparison between forest communities was done according to their ecological characteristics, index of biodiversity and the presence of invasive species.

According to the gained results, invasive species are very abundant both in natural forest communities, and in the planted forests on Deliblato Sands, although their species composition is slightly different. Their ubiquity influences the presence and abundance of native species, and by that the very structure of autochthonous forest vegetation. Invasive species inhabit all segments of all European woodland habitats, all vegetation strata, inhibiting the productivity of woodland ecosystems, disrupting forestry activities, degrading the habitat and affecting biodiversity.

## **Estimating leaf area index in coniferous forests in Switzerland using LiDAR**

*Claire Lavanchy, Peter Waldner, Christian Ginzler, Flurin Sutter, Anne Thimonier, Patrick Schleppi, Lorenz Walthert, Marcus Schaub*

Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland, [claire.lavanchy@wsl.ch](mailto:claire.lavanchy@wsl.ch)

Leaf area index (LAI) is an important biophysical indicator of the energy-, water- and CO<sub>2</sub>-fluxes between terrestrial ecosystems and the atmosphere. Therefore, it is a key input variable in many ecological process models on a stand or regional scale.

Methods for estimating LAI can be classified into direct and indirect methods. Direct methods such as harvesting and litter collection are labor intensive, time-consuming and only suitable for small areas. On the other hand, indirect methods such as hemispherical photographs and LAI-2000 canopy analyzer are generally faster and more convenient to implement. Remote sensing techniques such as satellite imagery and aerial photographs may also be attractive tools to derive LAI. Moreover, Light Detection and Ranging (LiDAR) allows extracting both, horizontal and vertical canopy structure of forests and is applicable to larger scales than ground-based measurements. In several studies (Solberg, 2009; Morsdorf et al., 2006; Mächler, 2010) LiDAR has proven to produce accurate estimates of LAI. However, in these studies the use of airborne LiDAR is limited to local or regional scale and not applied to national scale or the extent of operational forest inventory.

Therefore, in this research we aim to explore the capability of LiDAR for estimating LAI at a national scale. We are applying a method based on the Beer-Lambert law tested for Level II plots on coniferous forests in Switzerland and validate it with independent LAI measurements.

The objectives of this study are to (1) obtain accurate LAI estimates for all coniferous forests in Switzerland, (2) determine proper parameterization for the Beer-Lambert law model to fit for the entire study area, and (3) to validate our results using LAI estimates from ground measurements and LAI values predicted by regressions against simple stand parameters.

Our findings will provide valuable information on the use of LiDAR for estimating LAI for forest inventory at national scale.

## **European species distribution models as a tool for regional forest management planning (projects: Trees for the future & margins)**

*Karl H. Mellert, Wolfgang Falk, Ute Bachmann, Christian Kölling*

Bavarian Forest Institute, Germany, karl.mellert@lwf.bayern.de

At the Bavarian State Institute of Forestry (LWF) species distribution models (SDM) have been developed within the project “Trees for the Future” (Falk & Mellert 2011) to serve as a tool for site specific tree species selection. Regional models only covering a small portion of the species niche space are not appropriate for assessing effects of climate change on tree species (Mellert et al. 2011). Therefore, SDMs at the European level have been developed. The models explain presence/absence data from tree species at Level I monitoring plots (Fischer et al. 2010) unified with potential occurrences according to the Map of the Natural Vegetation of Europe. Macroclimate variables (WORLDCLIM) served as predictors. Within stepwise model selection the plausibility of the species-environment relationship was the most important criterion.

Models were validated by an independent data set and evaluated by mapping the predictions in Europe. Owing to the broad environmental gradients covered by Level I plots quite plausible macroclimatic models could be calibrated. Model uncertainty shows up especially at the edges of species distributions. Behind the background of climate change, occurrences at the warm and dry margins are most relevant as they represent xeric tolerance limits of tree species.

The results suggest the following measures to improve the first generation of SDMs within the following up project MARGINS (<http://margins.ecoclimatology.com/>) to specify tolerance limits more precisely:

- to improve quality of occurrence data by including each observation instead of only dominant species (1) and by refining models with marginal occurrences at the tolerance limits of the species (2)
- integration of relief (1) and soil information (2) as important predictors for site quality into the European models

Enhanced species occurrence data from ICP Forests monitoring including rare species and covering the whole continent provide an ideal spatial link between extreme and central occurrences in Europe.

## **The plant necromass and the ground layer vegetation are the clearest indicators of Cu and Ni deposition in a subarctic forest**

*Päivi Merilä, Kirsti Derome, Antti-Jussi Lindroos, Tiina M. Nieminen, Maija Salemaa, Pasi Rautio, Liisa Ukonmaanaho*

Finnish Forest Research Institute (Metla), Finland, [firstname.lastname@metla.fi](mailto:firstname.lastname@metla.fi)

The mining and metallurgical industry on the Kola Peninsula in Russia is one of the largest sources of heavy metal emissions in the northern hemisphere. The emission impact area of the smelters in Nickel stretches for over 100 km from the smelters, extending to Finland and Norway (Poikolainen et al. 2004, Myking et al. 2009). Here we present detailed results of copper (Cu) and nickel (Ni) concentrations in Scots pine dominated ICP Forests Level II plot located at Sevettijärvi in northernmost Finland, at a distance of 54 km from the emission sources in Nickel. Our aims were to evaluate the distribution of Cu and Ni pollution in a subarctic forest and to identify those ecosystem compartments showing the highest accumulation of heavy metals.

The highest Cu and Ni concentrations were found in plant necromass (non-foliar litterfall, bryophyte and lichen necromass, litter layer) and in the living ground layer vegetation (in bryophytes > in lichens). In these compartments the Cu concentrations (14–36 mg/kg) were 5–7 times higher and the Ni concentrations (20–45 mg/kg) were 17–31 times higher than the respective concentrations averaged for three other Scots pine dominated Level II plots located elsewhere in Finland. The Cu and Ni concentrations of both living needles and branches were 2–3 times and 2–12 times higher, respectively, than those on the reference sites. The upper mineral soil layers showed slightly higher Cu concentrations in Sevettijärvi than on the reference plots, while soil solution and stem wood showed no signs of Cu or Ni pollution.

In conclusion, our results indicate elevated Cu and Ni concentrations in most forest compartments at Sevettijärvi plot, which is most probably caused by the emissions from mining and metallurgical industry on the Kola Peninsula and do not originate from the geology of the site.

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## **Stocks and fluxes of carbon in two adjacent mountainous forest ecosystems in Greece**

*Panagiotis Michopoulos*

ELGO DEMETER. Forest Research Institute of Athens, Terma Alkmanos, Athens 115 28, Greece, mipa@fria.gr

The stocks and fluxes of carbon were examined in two forest ecosystems of oak and beech in the area of Ossa. It was found that the dissolved organic carbon in throughfall had higher concentration values in the oak forest. The litterfall in the oak forest contained higher amounts of carbon. Likewise, the ground vegetation in the oak forest was much denser and consequently had higher amounts of carbon. However, the soil in the beech plot had significantly higher stocks of carbon. The ratio C/N in litterfall did not differ significantly and therefore the higher stocks of carbon in the beech plot have to be accounted by the soil conditions of the two ecosystems. The lower pH values and temperatures (slowdown of decomposition) as well as the higher percentages of clay in the beech soil (protection against decomposers) contribute to the retention of higher stocks of carbon than that in the soil of the oak forest.

## Presence of *phytophthora* species on bioindication points in the Srem forest area

Ivan Milenković<sup>1</sup>, Nenad Keča<sup>2</sup>, Zlatan Radulović<sup>1</sup>, Dragan Karadžić<sup>1</sup>

<sup>1</sup>Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, ivan.milenkovic@sfb.bg.ac.rs,

<sup>2</sup>University of Belgrade-Faculty of Forestry, Kneza Višeslava 1, Belgrade, Serbia

Among many harmful factors of broadleaved trees, *Phytophthora* species are considered to be one of the main pathogens of fine root systems, causing typical and characteristic symptoms, including necrosis and wounds of mother roots, decay and progressive loss of fine roots, collar rot and bleeding cankers on stems, wilting of shoots and twigs, yellowing of leaves, dieback of crowns and branches, and increased crown transparency.

The aim of these studies were to (i) determine the presence of these pathogens in both clear and mixed oak stands in Srem forest area, (ii) the most frequent isolated species, (iii) and main hosts of these pathogens. Studies were performed in Srem forest area in three manage units (M.U.) two in Lower Srem including M.U. Grabovačko-Vitojevačko ostrvo (GVO), M.U. Kupinske Grede, and one in Upper Srem, M.U. Raškovića-Smogvica.

Sampling and isolation methods were performed according to Jung (2009) and Jung et al. (1996). Tissue samples were taken from necrotic zones and plated directly onto selective agar medium (V8A-PARPNH). Soil together with fine roots was sampled in the form of soil monoliths, measuring ~ 25x25x25 cm, and isolation tests were performed using oak, beech and cherry laurel leaves as baits for baiting method. Both symptomatic and healthy trees were sampled.

In total, 50 samples were taken from 7 different host species including *Carpinus betulus*, *Quercus robur*, *Fraxinus angustifolia*, *Acer campestre*, *A. tataricum*, *Populus* spp., and *Pyrus pyraeaster*. *Phytophthora* species were isolated from about 70% of samples. And after a detailed morphological and molecular identification, several different *Phytophthora* species have been confirmed, i.e. *P. cactorum*, *P. citricola*, *P. citrophthora*, *P. gonapodyides*, *P. plurivora*, *P. polonica*, *P. quercina*, and *P. lacustris* (previously known as *P. taxon* 'Salixsoil'). Many of those species are the first records in different ecosystems in Serbia.

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## **FORMIT simulation study on CO<sub>2</sub> mitigation potential in European forests by forest management strategies**

*Volker Mues, Konstantin Olschofsky*

Thünen Institute for World Forestry, 21031 Hamburg, Germany

The project "FORest management strategies to enhance the MITigation potential of European forests", short "FORMIT", is a collaborative project of 12 universities from all over Europe under the 7<sup>th</sup> Framework Programme of the European Commission. The project is led by Prof. Frits Mohren from the university of Wageningen, The Netherlands. Aims and methods of the FORMIT project are presented with special focus on the utilization of ICP Forests data by the University of Hamburg, UHH.

Aims and strategy of the project are described according to the FORMIT Annex I - "Description of Work" - of the project description:

In 2008, total anthropogenic emissions reached a record high level of 7.7 PgC (1015g carbon) emitted from fossil fuel combustion (Friedlingstein, 2008), with an additional 1.2 PgC in indirect emissions from land- use changes (Van der Werf et al., 2009). Continuation of this trend is expected to lead to significant changes in global ecosystems.

While forest management has to achieve multiple objectives, mitigation of climate change is becoming an increasingly important objective. This objective can be achieved by (i) increasing carbon storage in the terrestrial biosphere (soils and biomass), (ii) using renewable forest products as building material and (iii) substituting fossil fuels with biofuels. Managing forest ecosystems for sequestering carbon (mitigating climate change) is of increasing importance (Percy et al., 2003; Malmshheimer et al., 2008 ) and requires consistent and transparent monitoring of carbon algorithms across multiple scales.

Options for climate change mitigation must be compared and evaluated in multi-criteria analyses that include other forest values and ecosystem services provided by forest ecosystems and forest management. Forest management options may include selection of tree species and tree species mixtures, choice of rotation and silvicultural techniques, and specific measures to enhance carbon sequestration. Respective growth models which are able to be compiled for the wide variety of forest management traditions within Europe are under preparation.

ICP Forests data will be used for model validation. Use will be made especially from the Level II data on tree growth and those on soil, soil water, deposition regime (for classification of the ICP Forests sites). Net Primary Production (NPP) will be calculated where possible and used together with respective data from National Forest inventories for the validation of FORMIT model runs.

## **Predicting the vulnerability of forests to drought and biotic damage in Finland**

*Seppo Nevalainen, Seppo Neuvonen, Petteri Muukkonen, Mikko Peltoniemi and Martti Lindgren*

Finnish Forest Research Institute METLA, Finland, seppo.nevalainen@metla.fi

We are building a model-data system in order to estimate the vulnerability of forests to drought and biotic damage within the Climforisk-project. Forest health monitoring data from ICP Forests level 1 and damage assessments from NFIs will be used to generate models for the risks of different types of damages as functions of environmental factors. NFI- data, together with satellite images, topographic maps and climatic data provide the basic information. Modelling with a GIS-framework will be used to translate characteristics of individual sites into damage vulnerability profiles. As to abiotic damage, we modelled and derived a drought vulnerability map for the whole country. Our first pest/disease vulnerability models focus on the permanent or slowly changing site and stand related factors. The severity of *Gremmeniella abietina* (Scleroderris) epidemics was mostly affected by latitude, the proportion of pine and site fertility and relative elevation of the plot. The severity of pine sawfly (Hymenoptera, Diprionidae) damage was most clearly affected by latitude, thickness of the organic layer and proportion of pine in the stand. In further modeling, the probability of pine sawfly damage was also explained by current and previous years' low soil moisture, which was simulated with a simple weather data driven water balance model. The advantages and shortcomings of the ICP Forests level 1 data in relation to other data sources are discussed.



## **Macrofungi in monitoring of heavy metals and radionuclides in forest ecosystems**

*Milana Novaković<sup>1</sup>, Maja Karaman<sup>1</sup>, Vladislava Galović<sup>2</sup>, Milan Matavuly<sup>1</sup>*

<sup>1</sup> University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Trg Dositeja Obradovića 2, 21 000 Novi Sad, Serbia, milana.novakovic@dbe.uns.ac.rs,

<sup>2</sup> University of Novi Sad, Institute of lowland forestry and environment, Antona Čehova 13, 21 000 Novi Sad, Serbia

Fungi represent ubiquitous organisms in natural environments, including unpolluted habitats such as forest ecosystems as well as polluted urban areas. Over the last century it was proven that fungi play important role in uptake and accumulation of toxic substances, such as heavy metals and radionuclides, by physicochemical and biological mechanisms. This ability of fungi is essential in protection of other living organisms in their natural habitats. In forests ecosystems such a role is predominately dedicated to the mycorrhizal fungi and their plant partners.

For the first time in Serbia, the base was set for the systematic research of macrofungi in forest ecosystems. In 2011, five plots were designed in different forest associations on mountains: Vidlič, Tara and Kopaonik, in order to monitor and compare fungal diversity and to analyze the content of xenobiotics in sporocarps of macrofungi and their substratum. Determination of fungal species is based on morphoanatomical, as well as molecular approach. The content of heavy metals is analyzed by atomic absorption spectroscopy, while the level of radionuclides is measured by means of the reversed electrode „GMX“ type HPGe spectrometer. During first two years of research 222 macrofungal species were recorded. The content of heavy metals (Cr, Ni, Cd, Pb, Cu, Mn, Fe, Zn) and radionuclides (<sup>137</sup>Cs, <sup>226</sup>Ra, <sup>232</sup>Th, <sup>40</sup>K) was determined in 35 lignicolous and mycorrhizal species, including their substrates. Concentrations in samples from the same sites varied depending on fungal species. Generally, examined macrofungi contained higher levels of xenobiotics comparing to analyzed substrates. Samples from Mts. Tara and Kopaonik showed the most variations in terms of xenobiotic content.

Since these results represent preliminary data we expect that long term investigations of these areas would enable assessment of possible pollution and overall ecosystems condition, and thus will allow us to provide recommendations for improvement of forest management.

## Monitoring of forest ecosystems in Serbia

Saša Orlović, Zoran Galić, Verica Vasić, Milan Drekić, Miroslav Marković, Dejan Stojanović,  
Andrej Pilipović, Srdjan Stojnić

University of Novi Sad-Institute of Lowland Forestry and Environment, Serbia, sasao@uns.ac.rs

### **Keywords: monitoring, forest ecosystems, Serbia**

The intensive monitoring in Serbia is carried out on the plots that are located in the dominant forest ecosystems to study the cases and consequential relationships of anthropogenic and natural factors that cause damage to forest ecosystems. The main objective of intensive monitoring is to obtain better insight into the effects of air pollution and other stress factors on forest ecosystems. The intensive monitoring in Serbia was initiated in 2009 on the Fruška Gora Mt. The sample plot at Fruška Gora is situated in association with the dominant sessile oak (*Quercus petraea*), and there are also large-leaved European linden (*Tilia grandifolia*) and beech (*Fagus sylvatica*) trees present. A second intensive monitoring plot was established at locality Odzaci in 2010 with penduculate oak as dominant species. On both plots, the following factors are monitored: condition of tree crowns, chemical composition of tree leaves, tree growth rates, phenology, chemical composition of deposition, chemical composition of litterfall, soil chemical composition, ozone damage on leaves, ground vegetation and metrological parameters.

In the national project the monitoring of following forest types in Serbia are covered: Fraxineto – Querceto typicum, Querceto frainetto- cerris, Fagenion moesiace montanum, Blechneto – Piceto – Abieto – Fagetum sphagnetosum, Populus x euramericana, and coniferous plantation of Pinus nigra and Pseudotsuga sp. The monitoring includes monitoring of microclimatic conditions, water budget in ecosystem (soil, plant), soil chemistry and microbiology, carbon pool, plant vitality, macrofungi and insects diversity.

Monitoring of microclimate characteristics in stands included the analysis of the dynamics of temperature and relative humidity of air during the vegetation period. Dynamics of soil moisture was measured at different depths of soil. Monitoring of soil microbial activities included analysis of the abundance of azotobacters, the total number of bacteria, the presence aminoheterotrophs presence actinomycetes and the presence of fungi. On the investigated stands, stomatal conductivity and net photosynthesis are measured evapotranspiration.

## The FO<sub>3</sub>REST Project: what are the best indices to protect Mediterranean forests from ozone?

Elena Paoletti<sup>1</sup>, Pierre Sicard<sup>2</sup>, Marcello Vitale<sup>3</sup>, Alessandra De Marco<sup>4</sup>

<sup>1</sup> IPP-CNR, Sesto Fiorentino, Italy, e.paoletti@ipp.cnr.it,

<sup>2</sup> ACRI-ST, Sophia-Antipolis, France,

<sup>3</sup> UNIROMA1, Rome, Italy,

<sup>4</sup> ENEA, Rome, Italy

At present, the European standard for forest protection is the AOT40 index which is based on the atmospheric O<sub>3</sub> concentrations, although many studies suggest that a stomatal flux-based approach is scientifically-sound and would be an useful tool for O<sub>3</sub> risk assessment. In fact, stomatal uptake is limited by drought during summer in Mediterranean regions where ozone concentrations are high.

A comparison of total stomatal ozone uptake (POD0), threshold-based phytotoxic ozone dose (POD1), and concentrations exceeding 40 ppb (AOT40) for *Pinus halepensis* and *Fagus sylvatica* was conducted in South-eastern France and North-western Italy regions. Meteorological data, soil and canopy data and ozone concentrations for 2010 and 2011 were calculated from the coupled MM5-CHIMERE modelling system. The maps showed different distributions of AOT40 and POD0 in this area. Moreover, Canopy Moisture Content (CMC) was used as dependent variable for the assessment of potential impact of ozone on *Fagus sylvatica* and *Pinus halepensis* forests. AOT40 and POD0 increased when CMC decreased only for *P. halepensis* in both years, whereas *F. sylvatica* did not show any linear relationships among these predictors and. Regression Tree Analysis (RTA) showed that soil water content and temperature were the most important predictors affecting CMC in *F. sylvatica*. A more complicated pattern was evident in *P. halepensis* being CMC depending on several predictors, with POD0 and relative humidity as the most important. The use of POD1 instead of POD0 did not improve the relationship with CMC. We suggest POD0 as the best index for protecting Mediterranean forests from ozone impacts. This work was made possible with the contribution of the LIFE financial instrument of the European Union (LIFE10 ENV/FR/208) for the FO<sub>3</sub>REST project.

## **Forest Health Monitoring in the Alberta Oil Sands, Canada**

*Kevin E. Percy*

Wood Buffalo Environmental Association, 100-330 Thickwood Blvd., Fort McMurray, Alberta  
Canada T9K 1Y1. [kpercy@wbea.org](mailto:kpercy@wbea.org)

Canada has the world's third largest oil reserves, 97% of them in Alberta's Oil Sands. Of these, 20% are recoverable with mining, while most (80%) are recoverable by drilling (*in situ*). Production was 1.7 M bpd in 2012 and is expected to reach 3.5 M bpd by 2025. In the Athabasca Oil Sands Region combined industrial stack/non-industrial emissions of sulphur dioxide (SO<sub>2</sub>) are approximately 364 t/d. Emissions of nitrogen oxides (NO<sub>x</sub>) from industrial stacks/mine fleets/non-industrial sources are 310 t/d.

The Wood Buffalo Environmental Association (WBEA, [www.wbea.org](http://www.wbea.org)) is an independent, multi-stakeholder association based in Fort McMurray that monitors air quality, and air quality related environmental impacts including forest health within a 68,444 km<sup>2</sup> northern (550N to 600 N) latitude airshed. The oil deposits lie beneath the Boreal Plains Ecozone consisting of upland jack pine (*Pinus banksiana* Lamb.), aspen (*Populus tremuloides* Michx.), mixed forest, and wetlands. In 2008, WBEA implemented an ecological, forest health based approach for determining air quality cause - effect relationships. The forest health monitoring (FHM) network is stratified across air pollution patterns, and comprises ecologically analogous sites, specific indicators, co-measurement of predictors and responses in space and time. FHM is nested within a larger, multidisciplinary source to sink array of projects strategically structured to determine the fate and potential impact of Oil Sands air emissions across the landscape. The context supporting, and the WBEA practice of fully integrated air and FHM in Alberta's Oil Sands will be presented. The potential for beneficial collaboration between European and North American FHM programs will be discussed.

## Monitoring of the climate change effect on soil respiration in sessile oak (*Quercus petraea* L.) mixed stand

Andrej Pilipović<sup>1</sup>, Saša Orlović<sup>1</sup>, Srđan Stojnić<sup>1</sup>, Milan Drekić<sup>1</sup>, Milan Borišev<sup>2</sup>, Zoran Galić<sup>1</sup>

<sup>1</sup> University of Novi Sad - Institute of Lowland Forestry and Environment, Serbia, andrejpilipovic@yahoo.com

<sup>2</sup> University of Novi Sad – Faculty of Sciences – Department for Biology and Ecology, Serbia

Carbon dioxide emission from soils, known also as soil respiration, presents one of important components in ecosystem carbon cycle, which is strongly connected with climate change. Through the project entitled III 43002 “Biosensing Technologies and Global System for Long-Term Research and Integrated Management of Ecosystems” funded by Ministry of education and science of Republic of Serbia, on the level II ICP Forests monitoring plot situated at Mt Fruška gora, was installed 25x25m plot for soil respiration measurement.

Measurements were made in 2011-2012 periodically during vegetation period (May-October) with portable soil respiration measurement system instantaneously in the morning from 9 to 12 hours. In the same time, samples of soils were taken to determine soil moisture content. In 2011, periodicity was about 30 days, while in 2012 measurements were intensified to 15 day period. Besides soil respiration ( $R_s$ ) and soil moisture ( $M_s$ ), measurements of air temperature ( $T_{air}$ ) and humidity ( $R_H$ ), soil temperature ( $T_{soil}$ ) and water evaporation ( $W_{flux}$ ) were performed.

Results showed significant influence of soil moisture on soil respiration intensity at investigated site. Soil moisture and soil temperature were strongly correlated to air temperature and varied in the range of 13.1-22.3°C for  $T_{soil}$  and 12.2-30.2 for  $T_{air}$ . Soil respiration was significantly decreased in 2012, due to the cumulative drought effect for period 2011-2012. The difference between year 2011 and 2012 was highest in the autumn with values of 1,555  $\mu\text{molCO}_2\text{m}^{-2}\text{s}^{-1}$  for 28<sup>th</sup> September 2011, and 0.472  $\mu\text{molCO}_2\text{m}^{-2}\text{s}^{-1}$  for 1<sup>st</sup> October 2012. Evaporation was also decreased in 2012 and ranged from 0.066 to 0.021  $\mu\text{molH}_2\text{Om}^{-2}\text{s}^{-1}$ . In general, results showed temporal variability of soil respiration presuming that soil respiration was mostly affected by climatic conditions. In order to clarify effect of climatic factors, continue of further monitoring is required.

## **Spatial dendroclimatic response of forestry species from Romanian National Intensive Monitoring Network**

*Ionel Popa, Ovidiu Badea, Stefan Leca, Stefan Neagu*

Forest Research and Management Institute, Romania, popaicas@gmail.com

**Keywords: dendroclimatic response, growth index, climate, forest health, precipitation**

A synthetic indicator of various factors influence on forests health status is the tree growth, while dynamics of tree crown defoliation is an expression of their physiological status tendency. Typical dendroclimatological investigations were conducted in the Romanian intensive forest monitoring network (Level II). The main objective was to identify the driving climatic factors on tree growth and the spatial extend of the climate – tree ring width correlation. The relationship between tree growth index and main climatic factors was studied using bootstrap correlation and spatial correlation. As climate dataset was used the CRU 3.1 grid. For all oak species a positive correlation between the growth index and the amount of precipitation was noticed. The mean sensitivity, as a measure on tree reaction to climate, was minimum for spruce and silver fir and maximum for oak. Three pattern of climate – growth relationship were identified discriminated in accordance with *Quercus species*. The intensity and level of significance of correlation coefficients differ from one species to another and from one region to another. The growth of spruce from northern Romania (Rarau) is limited by temperature from previous October and current June-July, and spatial significant correlation were observed with the temperature from eastern and north-eastern parts of Romania. The influence of the altitude on the response to climate is evident for beech, being quantified two patterns: one for mountain beech (Sinaia and Fundata) and other for beech from hilly regions (Mihaești), where the driving climatic factor is precipitation recorded in May. Analyzing the spatial correlation between tree ring index and main climatic factor was possible to establish the regional representativeness of each plot from intensive forest monitoring. In addition, knowing the main limitative climatic factors on trees growth we can better analyze and forecast the evolution of health status of forests.

## **The protection status of relic polydominant forest communities of Serbia**

*Marko Rućando, Dragana Vukov, Mirjana Krstivojević, Miloš Ilić, Ružica Igić*

Faculty of Sciences, University of Novi Sad, Serbia, marko.rucando@dbe.uns.ac.rs

Serbia, as most parts of Balkan Peninsula, has different numbers of relic communities. Through history need for conducting research and monitoring has grown, but there is still the need to continue to examine this type of communities for their rich and diverse floristic composition. These relic communities are settled in typical refugia which are represented by specific climatic, geological, geo-morphological conditions that are the result of environmental conditions from past. Interfering factors in this refugia can modify and also disturb condition of relic polydominant communities and be responsible for their succession and depletion in direction to become impoverished relic communities with few relic edicator species, to oligo- and monodominant modern type communities. Aim of this study is to define distribution and to analyze protection status of these communities in Serbia. According to available data, 16 different relic polydominant forest communities exist in Serbia. Some of them are located in the areas protected within National Parks: six communities in the National Park Đerdap, two in the National Park Tara and one in the National Park Fruška Gora. They are also present in the areas of the lower nature protection status: Landscape of outstanding features, Nature Park and Natural Monument status, as well as in the areas that are currently not under any nature protection regime.

*short presentation*

## **Assessment of ozone flux for Swiss Level II plots; application – validation – further development**

*Marcus Schaub<sup>1,\*</sup>, Vicent Calatayud<sup>2</sup>, Beat Rihm<sup>3</sup>, Peter Waldner<sup>1</sup>, Elisabeth Graf Pannatier<sup>1</sup>, Patrick Büker<sup>4</sup>, David Simpson<sup>5,6</sup>*

<sup>1</sup> Swiss Federal Research Institute WSL, 8903 Birmensdorf, Switzerland, marcus.schaub@wsl.ch

<sup>2</sup> Fundación C.E.A.M., 46980 Paterna, Spain

<sup>3</sup> Meteotest, 3012 Bern, Switzerland

<sup>4</sup> Stockholm Environment Institute, University of York, York YO10 5DD, UK

<sup>5</sup> EMEP MSC-W, Norwegian Meteorological Institute, 0313 Oslo, Norway,

<sup>6</sup> Chalmers University, Gothenburg, Sweden

Under changing environmental conditions such as climate warming and increasing drought periods, the currently used concentration based exposure index for tropospheric ozone (AOT40) may be an inadequate measure to protect European forests from adverse ozone effects. Thus, there is a need for a more biologically relevant standard to protect forests from ground level ozone. A flux-based approach taking microclimatic conditions into account has been recommended (e.g. Mills et al., 2011).

Since 2000, the ICP Forests Expert Panel on Ambient Air Quality (EP AAQ) has measured ozone concentrations nearby Level II forest sites. Some countries, such as Switzerland have collocated ozone monitors (hourly real-time ozone concentrations) next to ozone passive samplers (average of bi-weekly ozone concentrations) since 2009. The Swiss National (NABEL) and cantonal Air Pollution Monitoring Networks, interpolated maps from the Federal Office for the Environment (FOEN) as well as the EMEP MSC-W model (Simpson et al., 2012) may be additional sources for data from calculated hourly ozone concentrations and estimated ozone flux values, respectively. For meteorological conditions, hourly Level II data and for soil moisture, data from tensiometers and EC-5 sensors will be used.

This integrative study aims at applying the latest parameterization, including a novel soil moisture algorithm (Büker et al. 2012) of the DO3SE model (Emberson et al. 2000) to assess ozone flux for selected Swiss Level II plots. The model will be run on the above indicated measured (passive & real-time) and calculated ozone concentrations. The outputs will be compared and discussed which may be a valuable contribution to the current efforts assessing ozone risk for forest ecosystems by means of ozone flux across Europe.



## **Twelve years of ozone and ozone effects monitoring in European forests – a critical review**

*Marcus Schaub<sup>1</sup>, Vicent Calatayud<sup>2</sup>, Marco Ferretti<sup>3</sup>, Richard Fischer<sup>4</sup> & contributing NFCs*

<sup>1</sup> Swiss Federal Research Institute WSL, 8903 Birmensdorf, Switzerland, marcus.schaub@wsl.ch

<sup>2</sup> Fundación C.E.A.M., Charles R. Darwin 14, Parc Tecnològic, 46980 Paterna, Spain

<sup>3</sup> TerraData Environmetr, 58025 Monterotondo M Mo, Italy

<sup>4</sup> Thünen Institute for World Forestry, 21031 Hamburg, Germany

Ground level ozone poses a serious threat to forest ecosystems across Europe. Ozone impacts on forests are of main priority for the UNECE Convention on Long-range Transboundary Air Pollution. Therefore, the ICP Forests Expert Panel (former Working Group) on Ambient Air Quality (EP AAQ) has collected data on ozone concentration and ozone effects, i.e. visible symptoms since 2000 on an annual basis on Level II forest sites across Europe. While ozone risk in Europe is being assessed by means of the AOT40 standard, numerous investigations are carried out and discussed concerning the data intensive ozone flux approach. This approach goes beyond the program of the EP AAQ and requires data and a close collaboration with other EPs (Meteorology and Phenology, Soil and Soil Solution) within ICP Forests.

The anticipated review will present an overview of available data and findings concerning the work being completed by national experts within the program of the EP AAQ. Emphasis will be put on data completeness, data quality, gap filling concerning field measurements, training courses and ring tests being conducted during the last 12 years. The state of the art will be discussed and gaps of knowledge as well as requirements from stake holders, researchers and national representatives will be outlined in the light of future needs for ozone risk assessments, completed by a possible road map for the near future.

This study will be a valuable review for stakeholders, the EP AAQ as well as for the ICP Forests Program Coordinating Group (PCG) as a basis for future decisions and envisaged efforts towards the ozone risk for European forests and its potential interactions with further tree response parameters under changing conditions.

## **Small-scale variation of floristic diversity of ground vegetation in forests under different environmental conditions**

*Walter Seidling<sup>1</sup>, Maija Salemaa<sup>2</sup>*

<sup>1</sup> Thünen Institute for Forest Ecosystems, Germany, walter.seidling@ti.bund.de

<sup>2</sup> METLA, Finland, maija.salemaa@metla.fi

In plant communities species-area relationships (SAR) have been used for comparing biodiversity of different areas, extrapolating species richness, predicting species loss, and assessing human impacts on biodiversity (Dengler 2009).

Since 1995 different sampling designs with varying sizes have been installed for monitoring of ground vegetation under ICP Forests. Designs based on several subplots per plot (Salemaa et al. 1999) allow the evaluation of species-area as well as grain-extent relationships. These circumstances should be taken as an opportunity to study species-area relationships in different vegetation zones and environmental conditions, as well as under different degrees of anthropogenic influence.

The following work packages can be established:

- i)** Collecting small-scale information and species data at subplot level from the NFCs or if possible directly from the central ICP Forest database along with general design information.
- ii)** Plot-wise parameterization of species-area relationships. Additionally grain-extent relationships have to be parameterised and a set of environmental drivers have to be prepared.
- iii)** Determination of the most influential abiotic and biotic factors determining small-scale variation of ground vegetation.

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## Use of mosses as biomonitors of nitrogen depositions in Slovenian forests

Mitja Skudnik<sup>1</sup>, Damijana Kastelec<sup>2</sup>, Zvonka Jeran<sup>3</sup>, Primož Simončič<sup>1</sup>, Daniel Žlindra<sup>1</sup>, Franc Batič<sup>2</sup>

<sup>1</sup> Slovenian Forestry Institute, Slovenia, mitja.skudnik@gozdis.si,

<sup>2</sup> Biotechnical Faculty, University of Ljubljana, Slovenia,

<sup>3</sup> Jožef Stefan Institute, Slovenia

In 2010 the third national moss survey was performed in Slovenia using mosses as biomonitors for nitrogen depositions in Slovenian forests. A systematic sampling approach was performed in summer 2010 aiming to test the influence of sampling site characteristics on nitrogen content in mosses. Moss samples (*Hypnum cupressiforme* Hedw.) were collected at 109 locations that were regularly distributed throughout the forest on a 8 x 16 km grid which is also part of the UN-ECE ICP Forest Level I sampling grid, including 18 locations near plots of the Intensive Monitoring Programme (UN-ECE ICP Forest) in Slovenia and neighbouring countries (Italy, Austria and Croatia). At each sampling location five subsamples of moss were collected. In the laboratory the samples were cleaned and dried. If there was enough moss in all five subsamples they were analysed separately, otherwise the composite samples were analysed. Additional explanatory variables were collected in the field or later by GIS. Deposition data from 14 UN-ECE ICP Forest Level II plots and from 4 national monitoring system stations (ARSO) were used to test how the nitrogen variation in moss tissue could be explained by the amount of nitrogen in the deposition.

The analysis show that average N content in moss tissue in Slovenia is 13.13 mg/g (CV = 20 %) with maximum value of 19.85 mg/g and minimum value of 8.51 mg/g. On 26 locations we tested the within and between site variation of N content in mosses. Linear models show that the variation of N content in mosses could be explained by distance between moss sampling location and nearest tree crown, distance to nearest shrub, yearly average amount of precipitation (2008-10), type of bedrock and percentage of cropland in radius 5 km.

All 18 sites for which N deposition data were available together revealed a significant correlation between N content in moss and N content in depositions (N-NH<sub>4</sub> + N-NO<sub>3</sub>).

## Antioxidant capacity of leaves of European beech from Serbia

Dubravka Štajner<sup>1</sup>, Saša Orlović<sup>2</sup>, Boris Popović<sup>1</sup>, Ružica Ždero<sup>1</sup>

<sup>1</sup> Faculty of Agriculture, University of Novi Sad, Serbia, stjajnerd@polj.uns.ac.rs

<sup>2</sup> Institute of Lowland Forestry and Environment, University of Novi Sad, Serbia

In the present study, ethanol extracts of leaves of *Fagus sylvatica* L. from three Serbian mountains: Kopaonik, Tara and Stara planina (FsK, FsT and FsS), with different climatic and environmental characteristic, were analyzed. The aim was to determine the total phenols, tannins, flavonoids and proanthocyanidins content, as well as the antioxidant activity of extracts in order to describe their adaptability to oxidative stress. The antioxidant activity was investigated by using ferric reducing power, permanganate reducing antioxidant capacity, and DPPH<sup>•</sup>, <sup>•</sup>OH, <sup>•</sup>NO and O<sub>2</sub><sup>•-</sup> antiradical powers. Lipid peroxidation (LP) was also determined as an indicator of oxidative stress. In FsT extract, the lowest LP (20.01 nmol MDA/mg protein), highest FRAP value (1061.54 FRAP units) and the best DPPH<sup>•</sup> antiradical power (ARP of 1.97) was observed. Also, the highest accumulation of proline (1.11 µg/g) and the highest protein content (264.9 mg/g dw) was determined in the same extract. The FsS extract was richer in pigment content than the other extracts, but less active than FsT in the DPPH test (ARP of 4.50). Finally, the extract from Kopaonik was characterized as containing a high amount of phenols (28.23 mg catechin/g dw), flavonoids (18.61 mg rutin/100g dw), tannins (15.55 mg catechin/g dw) and proanthocyanidins (130.56 mg leukocyanidine/100g dw), which might be the active compounds responsible for the antioxidant properties of the FsK extract and their oxidative stress adaptability.

## **Comparable analysis of defoliation on ICP forest sample plots in the Republic of Serbia 2009-2012**

*Tomislav Stefanović, Svetlana Bilibajkić, Zoran Poduška, Ilija Đorđević, Goran Češljar, Radovan Nevenić, Renata Gagić-Serdar*

<sup>1</sup> Institute of Forestry, Belgrade, areca@neobee.net

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The degree of defoliation of the crown on broadleaves and coniferous was researched on 130 permanent sample plots in the Republic of Serbia. Research includes assessment of defoliation at these permanent plots and defoliation was assessed on 5% interval. For the defoliation, missing in leaves and needles was main indicator, and so results don't have aim at determining the cause effect relationship but present condition of defoliation for the given period. Defoliation is presented in spatial distribution on the territory of Serbia. Results indicate that in this period major defoliation on broadleaves species is on *Quercus spp.*, while most resistant is *Fagus spp.* and *Carpinus spp.* On coniferous, *Pinus spp.* have most defoliation and *Picea abies* is the least affected.

## **Mycorrhizas of European forests: belowground indicators and their environmental drivers.**

*Laura M. Suz & Martin I. Bidartondo*

Imperial College London & Royal Botanic Gardens, Kew TW9 3DS, England, l.martinez-suz@kew.org

Mycorrhizas are major players in forest ecosystem function, but they are rarely used in measures of forest biodiversity or condition because large-scale, high-resolution, standardized and replicated data on mycorrhizal communities is lacking. Thus, we (1) assessed the mycorrhizal diversity of a preliminary subset of intensively-monitored ICP Forests plots across nine countries covering strong natural and anthropogenic environmental gradients, (2) tested for relationships between mycorrhizal community composition and forest condition, and (3) studied changes in mycorrhizal diversity and abundance. Our initial results highlight that nitrogen is a primary determinant of forest mycorrhizas; it reduces mycorrhizal diversity and changes evenness in both oak and pine plots. We are now expanding this analysis extensively to sample spruce, pine and beech plots from across the ICP Forests network.

## **Level I plots - quercus sp. - crown condition: the suggestion of definition of compulsory minimal number of annually assessments**

*Mara Tabakovic-Tosic*

Institute of Forestry, Belgrade, Serbia, mara.tabakovic@gmail.com

The stability of the forest ecosystems to a great extent depends on the impact, i.e. presence of the different harmful abiotic and biotic factors at the global and local levels. At the local level, it refers to the plant diseases, economically harmful living organisms, climate factors, local environment pollution, whereas at the global level it refers to the climate change, reflected in the global warming.

In the natural forests stands of Serbia, the species from *Quercus* genus are very common. The defoliating insects have special importance to all oaks. By the trophic fixation to the oak leaf they lead to the partial or total defoliation, which causes numerous adverse effects, including physiological deterioration of host plant, i.e. creation of the favourable conditions for the action of a number of secondary harmful factors, so it can be fatal for some trees and for the whole stands. Undoubtedly, defoliating insects are the significant factor of the destabilization and decay of forest ecosystems.

The crown condition assessment, which is conducted annually for the last 25 years, includes defoliation, discolouration and abiotic and biotic damage and it is mandatory for all levels at once a year, proved to be insufficiently, since there are great differences in the phenology of some species of defoliating insects. In Southeastern Europe, i.e. in the Balkan Peninsula, the condition of oak crowns should be assessed at least three times during the growing season: in April, when the early oak defoliators from the families Geometridae and Tortricidae are most active; in June, when the greatest damages are caused by *Lymantria dispar* L.; in August and September, when some species from family Noctuidae are active. This is the only way to determine the effect of this factor on the crown conditions in the current and forthcoming years.

## **A test of the nitrogen disease hypothesis for European forests.**

*Stavros D. Veresoglou<sup>1</sup>, Richard Fischer<sup>2</sup>, Alfred Fuerst<sup>3</sup>, Päivi Merilä<sup>4</sup>, Pasi Rautio<sup>5</sup>, Mara Tabakovic-Tocic<sup>6</sup>, Matthias C. Rillig<sup>1</sup>*

<sup>1</sup> Freie Universität Berlin, Institut für Biologie, Altensteinstr. 6, D-14195 Berlin, Germany

<sup>2</sup> Thünen Institute for World Forestry, D-21031 Hamburg, Germany

<sup>3</sup> Bundesforschungszentrum für Wald Seckendorff Gudent Weg 8, A-1131 Wien, Austria

<sup>4</sup> Finnish Forest Research Institute, Oulu, Finland

<sup>5</sup> Finnish Forest Research Institute (Metla), Northern Unit, P.O. Box 16, FI-96301, Rovaniemi, Finland

<sup>6</sup> Institute of Forestry, Kneza Viseslava 3, 11000 Belgrade, Serbia

The Nitrogen Disease Hypothesis (NDS) postulates that elevated N availability increases plant susceptibility to plant pathogens. Yet empirical data to support the NDS are scarce and limited to small geographical areas. We wanted to test the NDS on observational data, retrieved from the UNECE ICP Forests database, from 876 Level I plots throughout Europe. Stand health was evaluated either by visual assessment of crown condition (defoliation) or foliage discoloration. Foliar nitrogen to phosphorus concentration ratios (N:P) were used as a proxy of nitrogen availability. We hypothesized that even in the absence of air pollution data we would be able to detect a segmented response of stand health to N:P, namely a rapid increase of stand health for low nitrogen availability followed by a steady decline when nitrogen increases above a N:P threshold. Modelling was carried out in three phases: (i) environmental variables that could explain stand health measures were screened to obtain an optimal model; (ii) piecewise regression was implemented to identify the breakpoint for N:P separately for conifers and broadleaves; (iii) environmental-variables-inclusive models were fitted to assess significance of the N:P effect. Results are presented and discussed in the context of existing literature.



## **Comparison of tree phenological observations in ICP Forests and Slovene phenological network stations**

*Urša Vilhar<sup>1</sup>, Maarten de Groot<sup>1</sup>, Ana Žust<sup>2</sup>, Mitja Skudnik<sup>1</sup>, Primož Simončič<sup>1</sup>*

<sup>1</sup> Slovenian Forestry Institute, Slovenia, [ursa.vilhar@gozdis.si](mailto:ursa.vilhar@gozdis.si),

<sup>2</sup> Environmental Agency of the Republic of Slovenia, Slovenia

The study of developmental stages of trees in long time series is of increasing importance as an indicator of global climate change and associated biological responses. Manual phenological observations concentrate on obvious events based on a brief examination of trees. We used phenological data, first leaf unfolding (LU) and general leaf coloring (LC) of European beech (*Fagus sylvatica* L.) in Slovenia. The data originated from two sources:

a. the phenological archive of the Slovenian Forestry Institute, which included 5 ICP Forests Level II plots located in forest. The selection of trees and the observations were made in accordance with Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests of the UNEC for ECLTAP, Integrated Cooperation Program on Forests (ICP Forests).

b. the phenological archive of the Slovenian National Phenological Network of the Slovene Environmental Agency (SEA) within the Ministry of the Environment. They included 47 phenological stations where single trees were selected on the forest edge or in the open area. The selection of trees and the observations were made according with the rules for phenological observations performed within the phenological monitoring SEA and in accordance with Guidelines for Plant Phenological Observations of the World Meteorological Organization (WMO).

In this study we compared phenological data for first leaf unfolding (LU) and general leaf colouring (LC) of European beech from both methodologies. To test the data compatibility we built a model from SEA phenological monitoring data. The model was tested with ICP Forests data on LU and LC. The ICP Forests LU is shown to take place earlier and LC later. Advantages and weaknesses of both monitoring systems are discussed and suggestions for possible improvement and hybridization of both monitoring programs are presented.

## Soil water depletion on ICP Forests plots during extreme drought in 2012

*Urša Vilhar, Mitja Ferlan, Mihej Urbančič, Milan Kobal, Daniel Žlindra, Primož Simončič*

<sup>1</sup> Slovenian Forestry Institute, Slovenia, [ursa.vilhar@gozdis.si](mailto:ursa.vilhar@gozdis.si)

Soil water dynamics play an important role in the water supply of forest trees and understory vegetation. The aim of this study is to evaluate the influence of extreme drought in 2012 on forest soil water availability on ICP Forests Level II plots in Slovenia.

Seven forest stands in different eco-geographical regions were investigated with differing tree species composition and forest stand structure: 1 scotch pine (*Pinus sylvestris* L.), 1 black pine (*Pinus nigra* Arnold.), 1 oak (*Quercus robur* L.) and 4 beech (*Fagus sylvatica* L.) forest stands. Continuous 30 min soil water contents (SWC) at depths of 10 and 30 cm using Frequency domain sensors EC-5 (Decagon devices LTD) in the period from 2009 – 2012 were analyzed. Water-holding properties from 3 representative soil profiles for the prevailing soil types have been obtained. Meteorological data were obtained from the automated weather station in an open field close to the research plot. Ratio between Permanent wilting point (PWP) and measured SWC was used as an indicator of soil water depletion ( $SWD = 1 - (PWP/SWC)$ ). Values close to 1 represent no soil water depletion ( $SWC > PWP$ ), values close to 0 indicate severe soil water depletion ( $SWC \sim PWP$ ).

Average yearly SWC values were greater in the plots, where the amount of precipitation was highest. Lowest SWC were measured in the years, which experienced smallest amount of precipitation in the observation period. Measured SWC reached the level of PWP in the summer 2012 in all plots. Differences between 10 cm and 30 cm depth were dependent on distribution of precipitation and reach the same level only after high precipitations events. Ratio between PWP and measured SWC showed to be a good indicator of soil water depletion.

## The contribution of stemflow to total deposition

*Peter Waldner<sup>1</sup>, Anne Thimonier<sup>1</sup>, Karin Hansen<sup>2</sup>, Henning Meesenburg<sup>3</sup>, Richard Fischer<sup>4</sup>, Aldo Marchetto<sup>5</sup>, Mathieu Jonard<sup>6</sup>, Frédéric André<sup>6</sup>, Sonja Germer<sup>7</sup>*

<sup>1</sup> Swiss Federal Research Institute WSL, Switzerland, peter.waldner@wsl.ch

<sup>2</sup> IVL Swedish Environmental Research Institute, 100 31 Stockholm, Sweden

<sup>3</sup> NW-FVA, Nordwestdeutsche Forstliche Versuchsanstalt, 37079 Göttingen, Germany

<sup>4</sup> Thünen Institute, 21031 Hamburg, Germany

<sup>5</sup> National Research Council, Institute of Ecosystem Study, Italy

<sup>6</sup> Université catholique de Louvain, 1348 Louvain-la-Neuve, Belgium,

<sup>7</sup> ATB Leibniz-Institut für Agrartechnik, Potsdam-Bornim, Germany.

The atmospheric deposition of sulphur (S) and nitrogen (N) compounds affects forest ecosystems. Accurate estimation of the deposition to the forest is necessary in order to study how it affects. Exchange processes in the forest canopy makes it difficult to estimate the total deposition to the forest. One method for quantification of the total atmospheric deposition to forests is the filtering approach, i.e. applying canopy budget models to data bulk precipitation, throughfall and stemflow (Draaijers & Erisman, 1998; ICP Forests, 2010).

In this study, we evaluate the contribution of stemflow deposition to the total deposition for the major elements ( $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ) using a pan-European dataset (ICP Forests). We included time series with more than 3 years of seasonal or continuous stemflow, bulk precipitation and throughfall of 22 monoculture beech plots, 19 mixed plots.

The plot means of stemflow water amounts typically accounted for 5% to 20% of the total amount. This percentage was typically between 5% and 20% for  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{NO}_3^-$  and  $\text{NH}_4^+$  fluxes, but between 5% and 25% for  $\text{K}^+$  and  $\text{Na}^+$ . Maximum long-term means reached 30% for most and even 45% for some plots and solutes. In individual years percentages up to 60% have been reported in some cases. The relationship of stemflow deposition to basal area, stand age and precipitation amount will be discussed. This broad dataset might allow to approximate stemflow and improve the estimation of the total deposition for forest plots and years for which no stemflow measurements were performed.

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## **Reduced emissions of nitrogen and sulfur improved rain- and groundwater quality during the 1988-2010 period in The Netherlands**

*Esther J.W. Wattel-Koekkoek, Leo J.M. Boumans, Eric van der Swaluw*

National Institute for Public Health and the Environment, Bilthoven, The Netherlands, [esther.wattel@rivm.nl](mailto:esther.wattel@rivm.nl)

At the end of the previous century, emission-reducing measures were taken by the Dutch government in order to reduce air pollution and its negative effects on ecosystems. Nitrogen and sulfur emissions declined subsequently. We studied the effect of these measures on rainwater and groundwater quality, using data from the Dutch national monitoring networks on Air Quality, Acidification Trends and Groundwater Quality.

Rainwater has been sampled since 1978 at 31 different locations, initially using bulk collectors, but since 1988 by using wet-only collectors. From 2006 onward rainwater sampling was limited to 11 locations, with a sampling period for the acidifying components of 2 weeks. Shallow groundwater, the uppermost meter, was sampled during the winter of 1989-1990, at 150 locations in nature areas of the Dutch sandy region. Sampling was repeated four times at the same locations between 2000 and 2011. Groundwater at 10 meter depth was sampled using permanent wells.

After the measures to reduce N and S emissions were taken, the concentrations of these substances declined in rainwater, in the upper meter of groundwater as well as in groundwater at 10 meter depth. In 2010 rainwater had 39% less N compared to 1988, whereas the S concentrations had decreased by 73% compared to 1988. The N and S concentrations in the upper meter of groundwater in 2010 were found 56% and 59% less compared to 1988. There was also a decrease in N and S concentration in groundwater at 10m depth, but this was less clear.

Furthermore the aluminum/base cation ratio in the upper groundwater declined from 0.22 in 1988 to 0.16 in 2010. The analysis of the combined measurements indicates that emission-reducing measures improved rain- and groundwater quality, and also reduced soil acidification. This can contribute to ecosystem recovery.

## **Do throughfall sampler size and shape matter in deposition measurements – a comparison between harmonized and national samplers**

*Daniel Žlindra, Klemen Eler, Nicholas Clarke, Karin Hansen*

<sup>1</sup> Slovenian Forestry Institute, Slovenia, daniel.zlindra@gozdis.si

<sup>2</sup> Biotechnological Faculty, University of Ljubljana, Slovenia,

<sup>3</sup> Norwegian Forest and Landscape Institute, Norway,

<sup>4</sup> IVL Swedish Environmental Research Institute, Sweden

Within the FutMon project (LIFE07 ENV/D/000218; 2009-2010) an action took place, where national and harmonized samplers for bulk and throughfall deposition were compared. Within the experiment, conducted in 16 different European countries, each with its own monitoring procedures and sampling methods not only the sampling equipment was compared but also spatial design of sampling plots, sampling frequency and sampling procedures were on test. Since samplers and sampling designs vary considerably throughout Europe, a step-by-step approach was made where the harmonized sampling equipment was developed and tested first. The selected samplers were installed at one observation plot of each participating country where measurements of throughfall and bulk deposition ran in parallel with the national samplers for a period of one year. To evaluate the agreement between national and harmonized measurements of bulk and throughfall quantities (in mm), concentrations of selected chemical parameters (in mg/L) and depositions of these chemicals (in g/m<sup>2</sup>/yr) different statistical analyses were used: Altman-Bland plot, model II regression, repeated measures ANOVA.

Generally, good agreement between national and harmonized measurements was found for precipitation amounts, concentrations and deposition fluxes, with only few cases being the exception. Larger deviations between measurements were observed during larger precipitation amounts or in cases when measurement areas were too low or erroneously determined. No significant differences in deviations were found between gutter-shape and funnel-shape samplers or between measurements performed in broadleaved or coniferous forests. Results show that, in most cases, national sampling systems can be replaced by harmonized one without significant data discontinuity problems, or conversely, that the data on deposition measurements can be directly compared between countries.

## List of contributors

- Ahrends, B.  
 André, F.  
 Augustin, N.  
 Bachmann, U.  
 Badea, O.  
 Batič, F.  
 Bidartondo, M.I.  
 Bilibajkić, S.  
 Borišev, M. (2)  
 Boumans, L.  
 Braun, S.  
 Büker, P.  
 Calatayud, V. (3)  
 Calderisi, M.  
 Calvo, E.  
 Camino Serrano, M.  
 Češljarić, G.  
 Ciais, P.  
 Cionni, I.  
 Clarke, N. (2)  
 Cools, N. (2)  
 Cristofolini, F.  
 Cristofori, A.  
 de Groot, M.  
 De Marco, A. (3)  
 De Vos, B. (2)  
 De Vries, W.  
 Derome, K.  
 Đorđević, I.  
 Drekić, M. (3)  
 Eickenscheidt, N.  
 Eler, K.  
 Etzold, S.  
 Falk, W.  
 Ferlan, M.  
 Ferretti, M. (4)  
 Fischer, R. (5)  
 Fortmann, H.  
 Fuerst, A.  
 Gagić-Serdar, R.  
 Galić, Z.  
 Galović, V.  
 Germer, S.  
 Gielen, B.  
 Ginzler, C.  
 Gottardini, E.  
 Graf Pannatier, E. (3)  
 Griffiths, A.  
 Hajnal-Jafari, T.  
 Hansen, K. (6)  
 Horak, R.  
 Igić, R. (3)  
 Ilić, M. (3)  
 Jakovljević, T.  
 Janssens, I.  
 Jarak, M.  
 Jeran, Z.  
 Jonard, M. (2)  
 Karadžić, D.  
 Karaman, M.  
 Kastelec, D.  
 Keča, L. (2)  
 Klinck, U.  
 Kobal, M.  
 Kölling, C.  
 König, N.  
 Krstivojević, M. (3)  
 Lavanchy, C.  
 Leca, S.  
 Lindgren, M.  
 Lindroos, A.-J.  
 Luster, J.  
 Luysaert, S.  
 Marčeta, M.  
 Marchetto, A. (3)  
 Marković, M.  
 Matavuly, M.  
 Meesenburg, H. (3)  
 Mellert, K.H.  
 Merilä, P. (2)  
 Michopoulos, P.  
 Milenković, I.  
 Mues, V.  
 Muukkonen, P.  
 Napa, Ü.  
 Neagu, S.  
 Neuvonen, S.  
 Nevalainen, S.  
 Nevenić, R.  
 Nicolas, M. (2)  
 Nieminen, T. (2)  
 Nikolić, N.  
 Novaković, M.  
 Olschofsky, K.  
 Orlović, S. (4)  
 Pajević, S.  
 Paoletti, E. (2)  
 Pap, P.  
 Peltoniemi, M.  
 Percy, K.  
 Pilipović, A. (3)  
 Poduška, Z.  
 Poljaković-Pajnik L.  
 Popa, I.  
 Popović, B.  
 Proietti, C.  
 Radulović, Z.  
 Rautio, P. (2)  
 Reinds, S.  
 Rihm, B. (2)  
 Rillig, M.C.  
 Rućando, M. (3)  
 Salemaa, M. (2)  
 Schaub, M. (5)  
 Schindler, C.  
 Schleppe, P.  
 Schmitt, M. (2)  
 Seidling, W.  
 Sicard, P. (2)  
 Sicard, P.  
 Simončič, P. (3)  
 Simpson, D.  
 Skudnik, M. (2)  
 Staelens, J.  
 Štajner, D.  
 Stefanović, T. (2)  
 Stojnić, S. (2)  
 Sutter, F.  
 Suz, L.M.  
 Tabakovic-Tocic, M. (2)  
 Thimonier, A. (4)  
 Ukonmaanaho, L.  
 Urbančič, M.  
 van der Swaluw, E.  
 Vanguelova, E.  
 Vasić, V. (3)  
 Veresoglou, S.D.  
 Verstraeten, A. (2)  
 Vesterdal, L. (3)  
 Vilhar, U. (3)  
 Vitale, M. (2)  
 Vukov, D. (3)  
 Waldner, P. (7)  
 Walthert, L.  
 Wattel-Koekkoek, E.  
 Wellbrock, N.  
 Ždero, R.  
 Žlindra, D. (4)  
 Župunski, P.  
 Zürcher, A.  
 Žust, A.

## Contact

Programme Coordinating Centre of ICP Forests  
Thünen Institute for World Forestry  
Leuschnerstrasse 91  
21031 Hamburg, Germany  
[www.icp-forests.org](http://www.icp-forests.org)

## The Conference is hosted by

Institute of Forestry  
Kneza Visislava 3  
11030 Belgrade, Serbia  
Phone : +381 11 35 53 355 / +381 11 35 53 454  
Fax: +381 11 25 45 969  
[www.forest.org.rs](http://www.forest.org.rs)

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Hotel Metropol Palace, Belgrade  
Kralja Aleksandra Boulevard 69  
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