ICP Forests

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Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests

3rd ICP Forests Scientific Conference 2014

Abstracts

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Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests

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Foreword

European forest ecosystems represent an important component of the terrestrial carbon sink and provide a variety of services which depend on the sustainability of forests and their management.

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 is collecting data on forest condition (health, growth, biodiversity, nutrition) and environmental factors (air chemistry, deposition chemistry, meteorology) across Europe. This data is used by a large number of scientists working on different policy relevant research questions, including those raised in this conference.

The conference addresses the role of environmental stressors, in particular tropospheric ozone and nitrogen deposition, on the ability of European forests to sequester carbon and on the long-term sustainability of their health, productivity, diversity, and ability to provide ecosystem services.

It is aimed at scientists and experts from ICP Forests in particular and the UNECE ICPs community in general like the ICP on Integrated Monitoring, ICP Vegetation, ICP Modelling and Mapping, ICP Waters, their partners and respective stakeholders, as well as interested scientists and experts from related fields. Researchers engaged in successful projects, evaluations and modelling exercises based on ICP Forests data, or working in co-operation with ICP Forests are encouraged to present and discuss their work and results.

Main topics

- Past, present, and predicted impact of nitrogen deposition and ozone (and their combination) on growth, carbon sequestration, biodiversity, and the full set of ecosystem services provided by forests
- Past, present, and predicted impact of other biotic and abiotic stressors and their interactions

Targets

- Policy and outreach: The conference will provide an overview on the latest research in policy relevant fields, such as the impact of air pollution on the climate change mitigation potential of European forests, as well as on nutrient and water cycles, biodiversity, and forest health and vitality.
- Scientific platform: A comprehensive platform is offered for scientists working on the subjects to discuss scientific questions and share experiences.
- Data provider and user interface: The conference will link monitoring experts, researchers and modellers. Data users will benefit from background information related to the data sets. Data providers will profit from an advanced insight into latest statistical applications based on "their" data.

Programme

08:30-09:00	**Registration**
09:00-09:30	**Opening addresses**
09:00-09:10	Host country (NN)
09:10-09:20	ICP Forests (Michael Köhl)
09:20-09:30	Scientific Committee (Marco Ferretti)
09:30-11:10	**Session 1 - Nitrogen deposition, sustainability and climate change mitigation potential of European forests (Chair: Päivi Merila)**
09:30-10:00	Keynote: **R. Fischer**: Tracing atmospheric inputs throughout the nitrogen cycle – review from a European forest monitoring perspective.
10:00-10:20	**E. Vanguelova & R. Pitman**: Impacts of N input on forests and forest soil biogeochemistry in Great Britain.
10:20-10:40	**A. Verstraeten et al**.: Recovery from N saturation in Flemish forests under high N deposition.
10:40-11:00	**J. Johnson et al**.: Assessing the implications of atmospheric deposition and harvest-residue removal on nitrogen budgets in Irish forests.
11:00-11:05	**V. Buriánek et al**.: Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition.
11:05-11:10	**S. Fleck et al**.: Supraregional estimation of the base saturation of forest soils: A generalized linear model based on Level I data.
11.10-11:30	**Coffee break**
11.30-12:30	**Session 2 - Nitrogen deposition, sustainability and climate change mitigation potential of European forests (cont.) (Chair: Nathalie Cools)**
11:30-11:50	**M. Nicolas et al.**: Estimations of N deposition impacts may be improved through deposition maps: comparing two independent approaches for mapping bulk deposition at French scale.
11:50-12:10	**V. Šrámek et al**.: Aluminium species in forest soils and their potential toxicity to Norway spruce and European beech stands in the Czech Republic.
12:10-12:30	**M. Ferretti, G. Bertini et al**.: Changes in management, climate and nitrogen deposition explain recent deviation from expected growth in mature spruce and beech forests in Italy.
12:30-12:35	**T. Jakovljević et al**.: Comparing two permanent plots in Croatia and Italy with different levels of nitrogen deposition.
12:35-12:40	**P. Michopoulos** et al.: Nitrogen in a fir stand. Is there any risk of saturation?
12:40-14:00	**Lunch**

Programme (continued)

14:00-15:45	**Session 3 - Tropospheric ozone, sustainability and climate change mitigation potential of European forests (Chair: Nenad Potočić)**
14:00-14:30	Keynote: **M. Schaub et al**.: Ozone concentration, exposure and foliar injury in European forests – a ten-year study on permanent monitoring plots.
14:30-14:50	**F. Hayes et al**.: Impacts of ozone and nitrogen on silver birch.
14:50-15:10	**C. Proietti et al**.: The impacts of climate change and air pollution on forest health condition.
15:10-15:30	**E. Gottardini et al**.: Do ecosystem services have a biological cost? Ozone and climate regulation by Norway spruce forests along an Alpine altitudinal transect in Trentino, northern Italy.
15:30-15:35	**K. Sharps et al**.: New ICP Vegetation smartphone app for recording incidences of ozone injury on vegetation.
15:35-16:05	**Coffee break**
16:05-17:35	**Session 4 - Monitoring data, sustainability and climate change mitigation potential of European forests (Chair: Marcus Schaub)**
16:05-16:25	**P. Merilä et al**.: Above- and belowground carbon stocks in coniferous boreal forests in Finland.
16:25-16:45	**I. Popa et al**.: Influence of climate on tree health evaluated by defoliation in Level I network (Romania).
16:45-17:05	**R. Novotný et al**.: Forest tree nutrition and soil chemistry development on the intensive monitoring plots in the Czech Republic.
17:05-17:10	**Z. Galić et al.**: Soil moisture and water quality monitoring in Quercetum petraea stands.
17:10-17:15	**T. Levanič et al**.: Comparison of various descriptors of tree vitality – a case study of a beech intensive monitoring plot in Croatia.
17:15-17:20	**M. Salemaa et al**.: Ecological gradients of forest vegetation in eastern Fennoscandia.
17:20-17:25	**M. Tabaković-Tošić**: The condition of tree crowns at the sample plots of Level I – reliable or unreliable indicators of the vitality of main conifer species in Serbian forests.
17:25-17:30	**M. Tabaković-Tošić et al**.: Bark beetle outbreak in spruce communities within a sample plot (Level II) in the mountain Kopaonik in the period 2010-2013.
17:30-17:35	**M. Ferretti, V. Amici et al**.: Improved SFM Criterion 2 indicators for Italian forests?
17:35-18:00	**Final discussion and conclusive remarks (Chair: Marco Ferretti)**
18:00	**Closing**

Abstracts (main authors in alphabetical order)

Short presentation

Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition

Václav Buriánek, Radek Novotný, Kateřina Hellebrandová, Vít Šrámek

Forestry and Game Management Research Institute, Strnady, Jíloviště, Czech Republic

The current typological and phytosociological characterisation of the ground vegetation has been documented as an essential component of biodiversity at 154 Czech forest monitoring plots. Changes during the last 15 years have been described in regard to the deposition and concentration of nitrogen in the soil. Plots were classified as vegetation units in accordance with the UNECE and FAO nomenclature and on the basis of their potential natural vegetation and compared in terms of the occurrence and coverage of the indicative selected nitrophilous species. In all the soil horizons tested statistically significant differences in the C/N ratio were observed between areas with and without the presence of certain selected nitrophilous species (*Geranium robertianum, Impatiens parviflora, Sambucus nigra, Urtica dioica*). In the areas with the presence of the *Geranium robertianum* and *Urtica dioica* species, statistically significantly higher concentrations of nitrogen were recorded in some soil horizons than in those areas without these species. The findings concerning the influence of nitrogen on nitrophilous herbaceous indicators were compared with the European results obtained in the framework of the ICP Forests international programme and with those of other foreign studies.

Reference

Journal of Forest Science 59: 238–252 (2013)

Short presentation

Improved SFM Criterion 2 indicators for Italian forests?

Marco Ferretti[1], Valerio Amici[1], Giada Bertini[2], Stefano Carnicelli[3], Marco Calderisi[1], Gianfranco Fabbio[2], Angela Farina[4], Aldo Marchetto[5], Enrico Pompei[4]

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Besides being an essential component of the Earth system, forests provide a number of services to the society. Sustainable Forest Management (SFM) indicators were developed to monitor status and trends of forest resources and whether their management (in a broad respect) can be sustained. They involve several criteria, including forest health and vitality (Criterion 2). The Level II forest monitoring program CONECOFOR is the only source of data for several Criterion 2 indicators in Italy. Here we present a 1995-2012 study that investigated time trends of pollutant deposition, forest health and soil chemistry at the CONECOFOR sites.

Deposition of pollutants was investigated with respect to S-SO_4, N (N-NH_4+N-NO_3) and basic cations (Ca, Mg, K, Na). Due to its importance for the air pollution in the Mediterranean, ozone was also considered. Significant decrease of S and N deposition was obvious, while ozone displays an overall no significant trend.

Tree health was evaluated by means of two indicators: the frequency of trees with crown transparency (a proxy for defoliation) >25% (F>25) and the mean frequency of damage per tree. Significant decrease was obvious for F>25, while no significant trend has been detected for the frequency of damage.

Evaluation of changes in soil chemistry was constrained by the limited number of plots and the potential scarce consistency between measurement methods adopted in 1995 and 2006. Yet, no obvious change has been detected for the pH, C:N and C:N_index, CEC, BS, C_org.

Overall, results show quite an improvement of several SFM Criterion 2 indicators. However, while for some of them (i.e., deposition) results can be considered somewhat valid at a broader scale, it may be not so for e.g. tree health. Comparison with data from networks based on probabilistic design (e.g., NFI and Level I) is necessary.

Standard presentation

Changes in management, climate and nitrogen deposition explain recent deviation from expected growth in mature spruce and beech forests in Italy

Marco Ferretti[1], Giada Bertini[2], Marco Calderisi[1], Gianfranco Fabbio[2], Aldo Marchetto[3]

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Several factors have been advocated to explain increased forest growth rates: raising CO_2 level, augmented temperature, changes in precipitation pattern, fertilization by N deposition, management. Other factors, however, may have counteracted the positive growth response of forests in Italy. For example, concentration of tropospheric ozone has more than doubled over the period 1950-2000, and management practices (e.g. prescribed thinning) were often disregarded, with customary rotations missed and increased stand ages (on average). Here we used data collected at ten sites of the Italian Level II monitoring program (CONECOFOR) to investigate factors that may have influenced recent tree growth. Changes in tree growth (expressed in terms of mean increment rate) were estimated by comparing expected values from yield tables and recent (2000-2009) measured rates. We considered the following predictors:

- deviation between current age and the age of maximum mean growth rate as in the yield tables;
- changes in modeled precipitation (PR) and air temperature (AT) in the period 1961-1990 and 2000-2009;
- changes between past and present N deposition, estimated after global N maps (*http://daac.ornl.gov/CLIMATE/guides/global_N_deposition_maps.html*) rescaled taking into account the actual bulk deposition data measured at our sites and the year when the yield tables were created;
- changes in ozone concentration, estimated by the “historical” relationship between ozone concentration and elevation reported by Staehelin et al. (1994) for several sites across Europe.

Results show that changes in management, precipitation, temperature and N deposition were significant predictors of recent deviation of tree growth and - all in all - explained 98% of the variability ($p<0.001$). Ageing was the most significant factor contributing to the model, with a negative effect on growth. On the other hand, N deposition had a significant positive role, and this confirms recent results (Ferretti et al., 2014). Increased ozone concentration was negatively but not significantly related to growth changes.

Reference

Ferretti M. et al, 2014. Global Change Biology, doi: 10.1111/gcb.12552.

Staehelin et al., 1994. Atmospheric Environment, 28, 75-87.

Keynote presentation

Tracing atmospheric inputs throughout the nitrogen cycle – review from a European forest monitoring perspective

Richard Fischer

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Human activities such as production of artificial nitrogen fertilizers and fossil fuel combustion provide reactive nitrogen and have dramatically altered the global nitrogen cycle (e.g. Sutton et al. 2011). ICP Forests is the leading provider for information on nitrogen effects on forests at the European scale. On 55 intensive monitoring plots the overall decreasing trend for inorganic nitrogen deposition in the decade to 2010 was about 3% (Waldner et al. 2014). Despite these reductions, modeled critical nitrogen deposition load exceedances for 4700 large scale forest plots decreased by only 10 percent points from 1980 to 2000 (Fischer et al. 2014). In the 2nd European forest soil survey, one third of the coniferous plots was determined to have a high N status as indicated by a C/N ratio in the soil below 25 (De Vos and Cools in ICP Forests 2014). Recent results allow for a quantification of nitrogen effects on epiphytic lichens (Giordani et al. 2014) mosses (Skudnik et al. in ICP Forests 2014) and mycorrhizal richness and evenness (Suz et al. 2014). As concerns soil solution, the critical limit of 1 mg N L-1 was exceeded on half of 173 selected Level II plots (Iost et al. 2012). National studies mainly ascribe changes in soil solution concentrations to disruptions of the N cycle, caused by cuttings, storms, tree decline, or pest attacks (Pannatier and Jonard in ICP Forests 2014). Tree health and vitality are related to nitrogen deposition. Actual tree growth on intensive monitoring plots declined above a deposition threshold of 30 kg N ha-1 yr-1 (Etzold et al. 2013). Based on an analysis of foliar N/P ratios Veresoglou et al. (2014) show negative effects of increasing N on tree health, at least for conifers. Effects on tree crown defoliation are suspected specifically for beech (Ferretti et al. 2013). Based on deposition and climate change scenarios, De Marco et al. (2014) expect severely decreasing defoliation specifically of beech in southern Europe in the coming decades. Policy conclusions and recommendations for future research are drawn taking specifically into account newly available data from the ICP Forests large scale plots.

Reference

De Marco, A. et al. submitted, 2014: Impacts of air pollution and climate change scenarios on forest defoliation in Europe; Etzold, S. et al. 2013: Analysing the impact of atmospheric deposition and climate change on forest growth in European monitoring plots. Belgrade. Presentation at the 2nd ICP Forests Scientific Conference; Ferretti, M. et al. 2013: Defoliation and nitrogen deposition in Europe: a study on four tree species within the ICP-Forests network. Belgrade. Presentation at the 2nd ICP Forests Scientific Conference; Fischer, R. et al. 2014: Effects evaluation and risk assessment of air pollutants deposition at European monitoring sites of the ICP Forests. In: Steyn, D.G. et al. (eds.): Air pollution modeling and its application XXII (NATO Science for Peace and Security. Series C, Environmental Security); Giordani, P. et al. 2014: Detecting the nitrogen critical loads on European forests by means of epiphytic lichens. A signal-to-noise evaluation. For. Ecol. Manage. 311: 29–40; ICP Forests (ed.), 2014: Forest Condition in Europe, 2014 ICP Forests Executive Report (in press); Iost, S. et al. 2012: Spatio-temporal trends in soil solution Bc/Al and N in relation to critical limits in European forest soils. Water Air Soil Pollut. 223: 1467–1479; Sutton, M.A. et al. 2011: Too much of a good thing. *Nature* 472: 159–161; Martínez Suz, L. et al., submitted: Eutrophication and acidification drive ectomycorrhizal communities in Europe's oak forests; Veresoglou, S.D. et al. 2014: Exploring continental-scale stand health - N / P ratio relationships for European forests. New Phytol. (2014): 1-9; Waldner, P. et al., submitted: Temporal trends in atmospheric deposition of inorganic nitrogen and sulphate to forests in Europe. Atmos. Environ.

Short presentation

Supraregional estimation of the base saturation of forest soils: A generalized linear model based on Level I data

Stefan Fleck[1], Bernd Ahrends[2], Jan Evers[2], Winfried Riek[3], Henning Meesenburg[2], Uwe Paar[2]

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Under conditions of still high nitrogen immissions, sustainable growth of forests relies on nutrient availability. Especially base saturation of the soils needs to be sufficient in order to avoid nutrient imbalances. Considering the actual increasing demand for biomass from forests (branches and tops), sustainability of managed forests is at risk depending on harvest intensities and management regimes, which underpins the necessity to assess the management effects on base cation status of forest soils.

One means to achieve this is the prediction and regionalization of base saturation for analysis and planning purposes. As a tool to judge the state of forest soils, we developed a generalized linear model (GLM) to estimate base saturation over large geographical areas based on 650 Level I plots in Northwest- and East-Germany.

According to the GLM, two thirds of the observed variability in base saturation may be explained by the following variables: parent material, occurrence of podsolation, tree species, and potential cation exchange capacity. Deposition and climatic variables were of minor importance at the supraregional scale.

An application of the model shows the distribution of base saturation for Northwest- and East-German forest soils. The results point towards tree species as the most influential management option with regard to base saturation.

The statistical model is shown to be a useful tool for regionalization and a foundation for dynamic forest soil models that are needed to predict the effects of forest management and climate change on base saturation in practical forest planning under varying conditions.

Short presentation

Soil moisture and water quality monitoring in Quercetum petraea stands

Zoran Galić, Saša Orlović, Bojana Klašnja, Dejan Stojanović, Zoran Novčić

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

This paper shows the monitoring results of air temperature, relative humidity, soil moisture content and evaporation in *Quercetum petraea* stands during the past 3 years. The average monthly air temperature and relative air humidity are shown for July and August (the period of the year with the most prominent extremes). Thus, the average monthly temperature in July was the lowest in the year 2011 (20.7ºC) and the highest in the year 2012 (24.0ºC). Compared to the average air temperature in July, in August, the highest average monthly air temperatures recorded in 2012 was (23.8ºC) and the lowest in 2011 (22.2ºC).

During the period of research the greatest anomaly was recorded in September 2011. The average mean monthly air temperature was 20.4ºC. The average relative humidity in this period was lowest in August. The lowest value was in August 2012 (48.2%) and the highest in 2011 (65.3%).

The quantity of available water depended on hydrological conditions throughout the year. If hydrological conditions were closer to normal, the water soil supply was higher. Long periods of drought led to relatively uniform reductions in the quantities of available water in the soil, and thereby caused unfavorable conditions for plant growth. The highest rate of evaporation during the growth period was recorded in 2012 (648 mm).

* This study presents the results of project III 43002 financed by the Ministry of Education and Science of the Republic of Serbia.

Standard presentation

Do ecosystem services have a biological cost? Ozone and climate regulation by Norway spruce forests along an Alpine altitudinal transect in Trentino, northern Italy

Elena Gottardini[1], Fabiana Cristofolini[1], Antonella Cristofori[1], Marco Ferretti[2]

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Regulating air pollution and climate are important ecosystem services provided by forests. Among air pollution, ozone is particularly important because of its high values and wide distribution in remote forest areas. Forests may help in reducing ozone concentration because of stomatal and non-stomatal deposition. Ozone, however, can potentially affect the vegetation, leading to a reduction of photosynthesis with consequences from plant to ecosystem level. In a cost-benefit approach, this may be considered as a biological cost.

To assess the size of ozone and climate regulating services provided by Alpine forests, a fully randomized study was established along an altitudinal gradient (900 - 1500 m a.s.l.) in Trentino, northern Italy. Environmental variables (O_3, NO_2, T, RH, LAI) were measured between May and August 2013. Tree response variables (crown condition, needle weight, shoot length, chlorophyll fluorescence, C and O isotopes) were also investigated on mature Norway spruce trees.

Ozone concentration increased with altitude, both inside and outside of forests. Significant ($P<0.001$; Wilcoxon test) lower ozone concentrations, however, were observed within the forest (64.8 µg m^{-3}) with respect to open areas (71.3 µg m^{-3}). Effect of forests on temperature was particularly marked for maximum daily values.

As for response indicators, a distinct elevation pattern with concurrent increase of crown transparency and decrease of shoot growth, needle weight and photosynthetic activity potential was obvious. Nested within such a superimposed effect, the various response indicators were related to each other.

Estimates of ozone removal in terms of AOT40, relationship between exposure to ozone, ozone removal and tree- and plot-related variables will be presented and discussed. This will allow (i) the evaluation of possible biological costs of removing air pollutants and (ii) the functional interpretation of monitoring data. Altogether, this will help understanding the role of tree health on the regulating services provided by forests and *vice versa*.

Standard presentation

Impacts of ozone and nitrogen on silver birch

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Birch trees (*Betula pendula*) were exposed to factorial combinations of seven ozone and four nitrogen regimes for five months in solardomes at CEH Bangor in 2012 and 2013. The ozone regime was designed to investigate the benefits of changes in air quality policy that are anticipated to reduce both background and peak ozone concentrations, but with a larger reduction for the peaks. The range of ozone exposure seasonal means was 35 ppb to 70 ppb (24h mean) and the nitrogen treatments were applied weekly as ammonium nitrate to give treatments equating to 10, 30, 50 and 70 kg ha^{-1} yr^{-1}. Measurements were made at both the leaf level and at whole-tree level to investigate whether: nitrogen modifies the response to ozone; nitrogen and/or ozone treatment alter the DO_3SE parameterisations for birch; fluxes of ozone and carbon become uncoupled; whole-tree alterations in fluxes are a consequence of individual leaf physiological responses or via alterations in tree biomass.

The study found that:

- Ozone pollution decreased growth and therefore carbon sequestration of birch trees;
- Nitrogen treatment affected stomatal fluxes of birch and therefore nitrogen deposition should be accounted for when calculating ozone fluxes to inform assessments of vegetation at risk of ozone pollution;
- The cumulative effects of ozone and nitrogen pollution on trees require further study over several years as leaf-level measurements indicated that effects and interactions may occur over longer timescales.

Acknowledgement

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Short presentation

Comparing two permanent plots in Croatia and Italy with different levels of nitrogen deposition

Tamara Jakovljević[1], Aldo Marchetto[2], Giada Bertini[3], Nenad Potočić[1], Ivan Seletković[1]

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High amounts of atmospheric deposition of nitrogen (N) compounds are reported for large parts of Central and Southern Europe. The effect of increased N deposition on forest ecosystems has been debated. Under N-limitation, increased N deposition stimulates tree growth, but it can also affect an unbalance in the element ratio in plant tissues. Furthermore, it has been shown that excessive N deposition can increase tree sensitivity to pathogens, storms, and extreme weather conditions.

We compared intensive monitoring data for two forest plots located in Croatia (Jastrebarski lugovi, 110) and Italy (Bosco Fontana, VEN2) at similar latitude, both dominated by pedunculate oak (*Quercus robur* L.) and with different levels of defoliation. The Italian plot is located in the Po plain, one of the areas in Europe rich in industries and agriculture. The Croatian plot, located in the Pokupsko basin floodplain, is affected by the same factors, but to a lesser degree. The aims of this study are the following:

(1) to identify differences in N deposition and precipitation between the sites and across time;
(2) to evaluate differences in N uptake/release in the canopy and N ratio to other elements in foliage and soil;
(3) to evaluate if high amounts of N deposition can stimulate tree growth at different defoliation levels.

Preliminary results show that the percentage of trees with defoliation larger than 25% is higher in plot VEN2, where N deposition is stronger, than in plot 110, but in the latter the percentage shows a marked increase. Although the C:N ratio in the soil is higher in plot VEN2 than in plot 110, comparison of elemental composition of foliar tissues show that the C:N ratio is similar in the two plots, but the N:P ratio is higher in plot VEN2.

Reference

Jakovljević, T., Marchetto, A., Berković, K., Roša, J., Potočki, A., 2013: Atmospheric deposition measurement in the lowland forest ecosystem of Pokupsko basin in Croatia. Periodicum Biologorum 115: 363-370.

Standard presentation

Assessing the implications of atmospheric deposition and harvest-residue removal on nitrogen budgets in Irish forests

Jim Johnson[1], Thomas Cummins[2], Julian Aherne[3]

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The sustainability of forest ecosystems and their attendant services are dependent upon balanced nutrient budgets over the long-term. Forest ecosystems in Europe are subject to a number of disturbances, which have the potential to disrupt nutrient cycles. For example, the atmospheric deposition of nitrogen (N) can lead to an accumulation of N within a forest ecosystem. This in turn can have a number of important ecological impacts including changes to forest nutrition, floral diversity as well as nitrate leaching and soil acidification. In addition, the amount and type of biomass removed in harvesting has important implications for nutrient sustainability. Many jurisdictions are examining the feasibility of removing harvesting residues as a source of biomass for energy production. The move from conventional, 'stem-only harvest' to 'whole-tree harvesting', represents a potentially large increase in nutrient export from forest ecosystems. The ICP Forests programme, through long-term monitoring and regional surveys, contributes to the understanding of nutrient cycling in forest ecosystems and thus allows an assessment of ecosystems response to disturbance. In this study we assessed the impact of atmospheric N deposition and harvesting on N budgets for forests in Ireland. The majority of forests (>70%) in the country consist of highly productive plantations of fast growing conifers (primarily Sitka spruce, *Picea sitchensis* (Bong. Carr)) planted on organic or thin acid-mineral soils. Nitrogen deposition (NO_3^- and NH_4^+) ranges from less than 5 kg N ha^{-1} yr^{-1} in the west of the country up to 35 kg N ha^{-1} yr^{-1} in the south and east. We determined input-output budgets of nitrogen at 40 plots, consisting of ICP Level I & II sites, under two scenarios: stem-only and stem plus brash removal. Site-specific measurements of soil N and standing biomass were combined with observations of N concentrations in tree compartments to generate above- and below-ground nitrogen pools. Results indicate that when deciding on an appropriate harvesting method, the maintenance of balanced nitrogen budgets must be considered for these forests to remain sustainable.

Short presentation

Comparison of various descriptors of tree vitality – a case study of a beech intensive monitoring plot in Croatia

Tom Levanič[1], Nenad Potočić[2*], Ivan Seletković[2], Anamarija Jazbec[3], Damir Ugarković[3], Krunoslav Indir[2]

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To assess the possible influence of climate (temperature and precipitation during the vegetation period) on the vitality of common beech trees, we used several descriptors of beech vitality: defoliation, radial growth and concentration of mineral elements in leaves, as well as their interactions. For the subject of this study we selected the ICP Forests intensive monitoring plot 103, a mature beech stand with moderate mean defoliation. Data were compared for the period 1994 – 2007.

From year 1996 until 2004 there was a trend of increasing values of defoliation. After reaching a maximum in 2004, the values have a downward trend, although defoliation is still a lot higher than in 1996. The most significant changes happened in the years 1998, 2000-2001, and 2003-2004. Defoliation was higher in the years following a drought year than in drought years (2001 vs. 2000, 2004 vs. 2003).

Some differences in mineral element concentrations in leaves depending on the sampling year were also evident. For nitrogen low values were recorded in 2006, and for calcium and magnesium in the years 2000 and 2003 (drought years). Concentrations of phosphorus and potassium in beech leaves were generally low.

Statistical analysis revealed a positive correlation between tree-ring width and above average precipitation and negative influence of above average temperature in June. This indicates that this site could suffer from water stress if the temperature in June is above average and precipitation below average and that water is a limiting factor for tree growth on this site. We did not determine statistically significant relationships between foliar nutrient concentrations, crown condition and radial growth.

Reference

Bréda, N., Huc R., Granier A., Dreyer E., 2006: Temperate forest trees and stands under severe drought: a review of ecophysiological responses, adaptation processes and long-term consequences. Ann. For. Sci. 63: 625-644.

Standard presentation

Above- and belowground carbon stocks in coniferous boreal forests in Finland

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Empirical data on stand-level C stocks is necessary to be able to elucidate the effect of management practices on forests' carbon stocks and is valuable for validation of simulation models. In this study, we evaluated the amount and distribution of carbon (C) in different compartments of a forest ecosystem, including not only the tree stand and soil, but also such rarely reported C stocks as litter layer, ground vegetation and fine and small roots. The study included seven Scots pine and eight Norway spruce dominated stands belonging to the UN-ECE ICP Forests Level II programme in Finland. The average effective temperature sum and stand age of the sites ranged 658–1351 d.d. and 55–200 yrs, respectively. Among the study sites, the total C stock (needles, living and dead branches, stems, bark, stumps, coarse roots, fine and small roots, understory, litter, humus and mineral soil layers) ranged from 82 Mg ha^{-1} to 261 Mg ha^{-1}. The two largest C pools in the forest ecosystems were stems (mean = 29%), mineral soil (depth 0–40 cm; mean = 28%), and humus layer (mean = 14%). C stored in tree biomass accounted for 55% of the total ecosystem C stock. The proportion of C stored in potential logging residues or biofuel (needles, living and dead branches, stumps and coarse roots) was 44% and 31% of the tree C stock in northern spruce stands and in southern pine stands, respectively. The understory vegetation C stock was the largest in northern pine stands (1700 kg ha^{-1}), and the lowest in southern spruce stands (400 kg ha^{-1}).

Short presentation

Nitrogen in a fir stand. Is there any risk of saturation?

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The risk of nitrogen (N) saturation was assessed in a fir stand monitored during the period 1995 – 2009 in the area of Karpenisi (central Greece). It was found that the total N amounts in the soil (organic and mineral) reached a level of 10.864 kg ha^{-1} at a total depth of 80 cm. According to the literature, the stand is liable to a risk of N saturation. Despite these findings, the fir stand was not found to be N saturated taking into account that the N concentrations in the current year needles did not change significantly over time and the nitrate concentrations in the soil solution were very low. The dense ground vegetation probably contributed to N retention by the forest ecosystem.

Standard presentation

Estimations of N deposition impacts may be improved through deposition maps: comparing two independent approaches for mapping bulk deposition at French scale

Manuel Nicolas[1]*, Aude Pascaud[2], Luc Croisé[1], Jürgen Brommundt[3], Ralph Mettier[3], Lorenz Ammann[3], Stéphane Sauvage[2], Arnaud Mansat[4,5], Anne Probst[4,5]

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Evaluating critical load exceedances for nitrogen (N) is very sensitive to the estimates of deposition (Posch et al., 2008). The European Monitoring and Evaluation Programme (EMEP) provides deposition maps performed by using a mechanistic approach based on inventoried atmospheric emissions. As an alternative, bulk deposition can be mapped at the scale of the French territory by a co-kriging approach applied on data measured on 27 level II plots and using precipitation as a covariate with data from approximately 2 000 MétéoFrance stations. This approach was first performed on data averaged on the 6-year period 1993-1998 (Croisé et al. 2005) and was repeated for the consecutive 6-year periods 1999-2004 and 2005-2010. In addition to the cross-validation performed within the geostatistical approach, the results were tested on an independent national set of plots (MERA and BAPMON networks) where wet-only deposition was monitored. Despite a bias between bulk and wet-only deposition, the geostatistical estimates were significantly related to the spatiotemporal variations measured from 1993 to 2010 on this independent set of plots for both N-NO_3 (R^2=0.66) and N-NH_4 (R^2=0.56). Reversely, EMEP estimates averaged on the same 6-year periods were compared with bulk deposition measurements from level II plots: this resulted also in a significant relationship for N-NO_3 (R^2=0.55), but a rather poor one for N-NH_4 (R^2=0.18). Indeed the lack of performance of EMEP estimates for N-NH_4 can be mainly attributed to an important model overestimation in the western part of France, where the highest deposition expected from local intensive agriculture was not observed in bulk deposition surveyed for 20 years on level II plots. These results illustrate (i) the valuable input of geostatistical approaches in extrapolating bulk deposition measurements and (ii) the need for further understanding of the mechanisms behind N deposition, especially for N-NH_4.

Reference

Croisé L. et al. 2005: Two independent methods of mapping bulk deposition in France. Atmospheric Environment, 39: 3923-3941.; Posch M. et al. 2008: The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. International Journal of Life Cycle Assessment, 13: 477-486.

Standard presentation

Forest tree nutrition and soil chemistry development on the intensive monitoring plots in the Czech Republic

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Tree nutrition based on foliar analyses as well as chemical properties of forest soils is studied at the ICP Forests intensive monitoring plots in the Czech Republic since the mid 1990´s. Soil surveys have been conducted at five year intervals; foliage analyses every second year. At some of the plots atmospheric deposition (bulk and throughfall) are measured continuously giving a general overview about the acidification load. Although the period with the most significant air pollution load (~1960-1990) had passed before our plots were established we can still observe continuing adverse effects on forest soils. Soil pH has been stable or slightly increasing in the last fifteen years, on the other hand we have found a continuing decrease of exchangeable base cations (mainly Mg and Ca) in the mineral soil. These changes are partly connected with the increased consumption of these nutrients by trees, which may be related to a high nitrogen deposition – the most serious decrease has occurred in the layer of maximum rooting; in spruce stands at a depth of 0-20 cm, in beech stands at a depth of 20-40 cm. On plots with the historically highest deposition load the soil is extremely poor in base nutrients within the whole vertical profile independent of tree species. In foliage samples an increasing proportion of nitrogen to other nutrients has been identified; nutrition imbalance was detected at some of the plots. The results indicate a potential risk for the next generation of forest stands in terms of sustainability of forest management and ecosystem nutrient cycling.

Standard presentation

Influence of climate on tree health evaluated by defoliation in Level I network (Romania)

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The dynamics of tree defoliation are a synthetic indicator of tree and forest health. Defoliation is a result of cumulative interactions of stress factors like climate, air pollution, biotic factors or management system. The large scale forest condition monitoring network (Level I) offers the possibility to investigate, on statistical bases, the correlations between tree crown defoliation and climate or air pollution parameters because of its highly variability at species and spatial level. Using the crown defoliation database (Level I) for the period 1992–2012 linked with the E-OBS climate grid database (temperature, precipitation) we evaluate the correlation between crown defoliation index (mean defoliation percentage and tree frequency in different defoliation classes).

The precipitation regime has, generally, a negative correlation with defoliation percentage mainly in *Quercus* spp., *Robinia pseudoacacia* and *Carpinus betulus*. Increase of temperature induces an increase of defoliation intensity and frequency of trees defoliated in classes 3-4 (defoliation > 65%). The multiple stepwise regression analyses show a small variance explained by climatic factors, with a maximum of 20-30%. For *Picea abies* and *Fagus sylvatica* the explained variance of defoliation intensity by climate is below 10%.

Preliminary results show a small influence of meteorological factors on tree defoliation. It is necessary to include in the analysis other factors like age, altitude and air pollution, too. In this way the role of climate conditions and air pollution on crown defoliation and, consequently on the forest health status may be considered as a key task at the European level , in order to identify the best policies able to mitigate the impacts of future climate and air pollution. Thus, policies can be suggested for an appropriate forest management.

Standard presentation

The impacts of climate change and air pollution on forest health condition

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Climate change and air pollution are two significant stressors affecting forest health and vitality of European forests and are highly relevant for sustainable management of European forests. Temperature is expected to increase between 3°C in central Europe and 4-5°C in the boreal region and parts of the Mediterranean area by 2100, according to the latest climate change scenario projections for Europe (Loustau *et al*., 2005). High temperatures may accelerate acid deposition, increase emissions of CO_2 and reactive trace gases from plants, thus reducing the CO_2 removal by vegetation and promoting tropospheric ozone formation (Guenther *et al*., 2006), causing regional tree die-off events and contributing to the global reduction of the carbon sink efficiency of forests. In this framework, evaluation of forest health condition, monitored by the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), is essential. The study aims to estimate future forest health conditions under three climate scenarios and one air pollution scenario in 2030. The methodological approach consists of the use of the Random Forests Analysis (RFA) and general regression models (GRM). Europe-wide, an improvement of forest health was found under most scenarios unless for some species (e.g. *Fagus sylvatica* and *Quercus ilex*), where a negative impact of climate change is predominant. Our results provide information on the regional distribution of future forest health, a key task at European level, for identifying policies able to counteract negative impacts of climate change and air pollution.

Reference

Loustau, D., Bosc, A., Colin, A. et al. 2005: Modeling climate change effects on the potential production of French plains forests at the sub-regional level. Tree Physiology 25: 813-823.

Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P.I., Geron, C., 2006: Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature). Atmospheric Chemistry and Physics 6: 3181-3210.

Short presentation

Ecological gradients of forest vegetation in eastern Fennoscandia

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In terms of climate and soil, the environmental conditions in Finland and in Russian Karelia are relatively similar, but structurally the forests in these countries differ significantly. The general aim of the study was to analyze the variation in the understorey vegetation of upland forests in relation to climatic factors, soil fertility, and stand structure in eastern Fennoscandia using ordination and GIS techniques. Further, our aim was to compare the zonal pattern of forest vegetation between the regions and to determine the “hotspot areas” (without any protection) where the number of plant species is the highest. The study material is based on systematic surveys carried out in Finland in 2006–2007 (EU Forest Focus BioSoil) and in Russian Karelia in 2008–2009 using comparable methods. The data (latitudinal range 60^o–66^oN) includes information on plant species richness and percentage cover, tree stand characteristics, chemical variables of soil, and modeled climatic indicators on 419 permanent plots in Finland and 147 plots in Russian Karelia.

The species composition was relatively similar on both sides of the border, though certain eastern flora found in Karelia and Karelian Isthmus was lacking in Finland. In the NMDS ordination the plots were located in accordance with the dominating tree species (Scots pine > Norway spruce > *Betula* spp. > Aspen and *Alnus* spp.) indicating that soil fertility level was the main compositional gradient. The most species-rich forests were found in SW Finland and Karelian Isthmus in areas with high Ca concentration and high pH in the soil organic layer. In addition to fertility, location along a south – north gradient caused differentiation in forest vegetation giving information for the zonation of boreal forests. Vegetation in South Karelia (Middle Taiga) resembled the southern-middle boreal vegetation in Finland and that of North Karelia (North Taiga) the middle-northern boreal vegetation in Finland.

Keynote presentation

Ozone concentration, exposure and foliar injury in European forests – a ten-year study on permanent monitoring plots

M. Schaub[1*], V. Buriánek[2], M. Ferretti[3], E. Gottardini[4], F. Hayes[5], I. Hůnová[6], T. Jakovljević[7], PE Karlsson[8], A. De Marco[9], M. Miroslava[10], M. Nicolas[11], R. Novotny[2], H. Pavlendova[12], S. Rajkovic[10], D. Silaghi[13], W. Werner[14], V. Calatayud[15]

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[6] *Czech Hydrometeorological Institute, Czech Republic*
[7] *Croatian Forest Research Institute, Croatia*
[8] *IVL Swedish Environmental Research Institute, Sweden*
[9] *ENEA, Italy*
[10] *Institute for Forestry, Serbia*
[11] *Office National des Forêts, France*
[12] *National Forest Centre, Slovakia*
[13] *Forestry Research and Management Institute ICAS, Romania*
[14] *University of Trier, Germany*
[15] *Fundación CEAM, Spain*

Ground level ozone poses a serious threat to forest ecosystems across Europe and represents a priority for the UNECE Convention on Long-range Transboundary Air Pollution. The ICP Forests Expert Panel on Ambient Air Quality (EP AAQ) has coordinated the monitoring of ozone concentration and effects (i.e. foliar injury on native vegetation) since 2000 on an annual basis on intensive long-term forest monitoring sites across Europe (Level II). Methodologies, including quality assurance such as data harmonization, completeness and plausibility tests have been applied according to the ICP Forests Manual, parts X and XV (Schaub et al. 2010a & 2010b). Here, the authors will evaluate the available data on ozone concentration, exposure and foliar injury that have been collected within the ICP Forests across Europe from approx. 80 – 150 plots and over 1000 native species. Emphasis will be put on European scale analyses for i) spatial and temporal trends for ozone concentration; ii) AOT40 based on passive samplers and different assessment methodologies; iii) comparison between measured concentration/exposures and EMEP estimates; and iv) foliar injury occurrence in relation to ozone concentration and ozone exposure respectively.

When considering the set of stress factors and response indicators monitored within the ICP Forests, this analysis will favor a comprehensive evaluation of ozone risk for European forests.

Reference

Schaub, M. et al. 2010a: Monitoring of Ozone Injury. Manual Part X, 22 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 [http://www.icp-forests.org/Manual.htm].

Schaub, M., et al. 2010b: Monitoring of Air Quality. 13 pp. Part XV. 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 [http://www.icp-forests.org/Manual.htm].

Short presentation

New ICP Vegetation smartphone app for recording incidences of ozone injury on vegetation

Katrina Sharps[1] Gina Mills[1], Jim Bacon[2], Harry Harmens[1], Felicity Hayes[1] et al.

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In 2007, the ICP Vegetation published a synthesis report documenting over 500 incidences of ozone injury on crops, grassland species and shrubs growing in the field under ambient air conditions in 17 countries of Europe (Hayes et al., 2007). We plan to revisit this study by compiling new spatial data on current incidences of ozone injury. Using smart-phone technology for i-phones and android phones, and web-based recording methodology we are developing a new way of recording incidences of ozone injury in the field. A new app has been developed that will allow participants to upload photographs of ozone injury direct from the field together with the coordinates for the location where the injury was detected (derived from a zoom-able Google map). Participants will be taken through a series of questions designed to assist with quality assurance, including being asked if they have previous experience of identifying ozone damage or plant diseases and recent weather conditions. The app could be used anywhere in the world and thus is suitable for use in the outreach activities as well as the European activities of the ICP Vegetation. We would like to encourage as many people as possible to participate in using the app to record ozone injury in 2014 allowing us to fully test the app by developing a large database for analysis.

The web-based recording facility is available at our webpage: http://icpvegetation.ceh.ac.uk.

Acknowledgement

We thank the UK Department for Environment, Food and Rural Affairs (Defra) and the UK Natural Environment Research Council (NERC) for funding this project.

Reference

Hayes, F., Mills, G., Harmens, H., Norris, D., 2007: Evidence of widespread ozone damage to vegetation in Europe (1990 – 2006). Programme Coordination Centre of the ICP Vegetation, Centre for Ecology and Hydrology, Bangor, UK. ISBN 978-0-9557672-1-0, http://icpvegetation.ceh.ac.uk/publications/documents/EvidenceReportFINALPRINTEDVERSIONlow-res.pdf

Standard presentation

Aluminium species in forest soils and their potential toxicity to Norway spruce and European beech stands in the Czech Republic.

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The composition of Aluminium ionic species in forest soils has been studied at ICP Forests plots with prevailing Norway spruce or European beech in the Czech Republic. General soil chemistry was characterized by the results of the ICP Forests BioSoil survey; the interaction of trees and soil was described by the measuring of quantity and vitality of fine roots (20 cores per plot) and their chemical composition (Al, Ca, Mg, K); vitality of trees was provided by the regular defoliation assessment. Results show that the potential aluminium toxicity has a significant effect on forest health in European beech stands. Norway spruce is more influenced by the availability of nutrients – mainly base cations in forest soil. These – somewhat surprising – results can be explained by the different root distribution of the two studied species. Norway spruce grows at more acidified sites but it creates an extreme surface root system with the majority of fine roots located at the border zone between organic layer and mineral soil. In this part of the soil aluminium is prevailingly situated in organic bounds and the concentration of its potentially toxic ionic forms as Al^{3+} is very low. On the other hand trees can suffer from the limited nutrient supply from the thin rooting zone, especially in periods of drought. European beech, on the other hand, is planted at more favourable forest sites. It has a deeper root system with an important share of fine roots at a depth between 20 and 40 cm where the concentration of Al^{3+} can be significant.

Short presentation

The condition of tree crowns at the sample plots of Level I – reliable or unreliable indicators of the vitality of main conifer species in Serbian forests

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The massive desiccation of individuals or groups of trees in 2013 was reported in all areas of Serbia. It was most intense in the spruce and fir, and about eight-fold less intense in the Austrian and Scots pines. The intensity of desiccation is expressed by the timber volume marked for the sanitation felling and in the case of spruce and fir it is 103,239 m^3, and in the case of pines it is 13,051 m^3.

On the territory of the Republic of Serbia monitoring of the forest condition in 2013 was performed on the 17 sample plots with main conifer trees (spruce – 146 trees, silver fir – 69, Scots pine– 56, Austrian pine 56). Field work for the data collection (observations and measurements) was carried out in the period June – September, and the result, at least when the reported desiccated trees are concerned, greatly differs from the above stated conditions in Serbia in general. Namely, during the monitoring of the crown condition no desiccated tree of spruce, fir or Scots pine was reported, and in the case of the Austrian pine it accounts for only 1.5% of the trees which were assessed (Stefanović et al, 2013).

The reasons for a great divergence of the above results lie in the fact that the density of the sample plots in the rectangular grid 16 x 16 km is too small for the monitoring of the desiccation phenomenon of the individual and groups of trees, and, consequently, for acquiring the real picture of the process. In addition, the statistical sample (the number of trees of some species) is not representative and is too small. It is not possible to apply the result of the monitoring of the crown condition of, for instance, 146 spruce trees, to the 57,532,098 individuals of this species that are present in the forests of Serbia.

Reference

Stefanović, T., Bilibajkić, S., Nevenić, R., Đorđević, I., Poduška, Z., Češljar, G., Gagić Serdar, R., 2013: Results of research of defoliation on bio-indicator plots in Republic of Serbia in 2013. Sustainable Forestry 67-68: 95-101.

Short presentation

Bark beetle outbreak in spruce communities within a sample plot (Level II) in the mountain Kopaonik in the period 2010-2013

Mara Tabaković-Tošić[1], Radovan Nevenić[1], Goran Češljar[1]

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The Level II sample plot, established for the purposes of monitoring and assessment of impacts of air pollution on forest ecosystems, is located in a pure spruce stand, with trees above 60 years of age, with north-west aspect and at 1720 m a.s.l. in the area of the NP Kopaonik. Two of the most dominant species of bark beetles (*Ips typographus* and *Pityogenes chalcographus*) have been recorded since the establishment of the sample plot (2010) (Nevenić R., Tabaković-Tošić M. et al., 2011). In the first year, the attack was of low intensity one and it was scattered throughout the stand, but in 2013, it reached its culmination in some parts of the stand on the sample plot. Out of the total number of trees (195), 26 or 13.4% were attacked by these two most significant spruce bark beetle species. Out of the total number of attacked trees, 19 or 73.1% died.

The results of the research study reveal a number of factors that have caused this outbreak. There is no doubt that the following factors had significant effects on the reduction of the host vitality, which further increased their predisposition for an increasing attack of these two existing species of bark beetles: climate change, UV radiation, ozone, tree aspect, stand age, and the absence of sanitary felling.

Reference

Nevenić, R., Tabaković-Tošić M., Rajković S., Rakonjac Lj., Miletić Z., Marković M., Bilibajkić S., Stefanović T., Stajić S., Čokeša V., Radulović Z., Poduška Z., Gagić-Serdar R., Đorđević I., Češljar G., 2011: Monitoring and impact assessment air pollution and its effects in forest ecosystems on the territory of the Republic of Serbia – monitoring of forest condition, Level I and Level II, Monography, Institute of Forestry, Belgrade. ISBN 978-86-80439-28-0. 295:9-123

Standard presentation

Impacts of N input on forests and forest soil biogeochemistry in Great Britain

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Critical N load maps currently indicate that the majority of both broadleaf and conifer woodland in the UK exceeds the limits for nutrient nitrogen, although widespread effects of this excess deposition have not been evident, except at woodland edges. The greater exceedance risk near emission sources is of particular concern because deposition increases substantially closer to the source. Edge effects are very important for small plantations and thus of a high significance to woodland in England where forests are fragmented and there is intensive agricultural and farming activities, in addition to intensive road traffic. It is crucial to understand the variability and nature of effects of N deposition on forest and soil biochemistry at forest stand, regional and national scales.

The main findings from experimental research, EU long term extensive and intensive forest monitoring (Level I and Level II) and spatial soil surveys (BioSoil) undertaken by Forest Research during the last 20 years, summarising our current understanding of the impacts on N deposition on broadleaved and coniferous forests and forest soil biogeochemistry across Great Britain will be presented.

The main findings from a detailed gradient study from point sources of N pollution in East Anglia and regional comparisons between forest areas with low (Alice Holt) and high N deposition (Thetford) will be also presented. The impact of N on forest growth, physiology, soils and forest nutrient and carbon cycling will be included alongside forest biological responses to N input.

Standard presentation

Recovery from N saturation in Flemish forests under high N deposition

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The objective of this study was to evaluate the recovery from nitrogen (N) saturation in forests under high N deposition in Flanders, northern Belgium. Deposition and soil solution concentrations of inorganic nitrogen (DIN) and total N were measured at five ICP Forests intensive monitoring plots (1 *Pinus sylvestris*, 1 *P. nigra* subsp. *laricio*, 2 *Fagus sylvatica* and 1 mixed *F. sylvatica* – *Quercus robur*) from 1996 till 2013 (DIN) and from 2005 till 2013 (total N). Deposition and soil solution concentrations of organic nitrogen (DON) were calculated as total N - DIN. The sodium mass balance approach was used to calculate N fluxes through the soil. In 1996 all forests were strongly N saturated, indicated by year-round elevated nitrate (NO_3^-) leaching. Despite an overall decrease of DIN depositions, DIN + DON depositions still amounted to 22-32 kg N ha^{-1} y^{-1} in 2013. This coincided with a decline of NO_3^--leaching, and an increase of the DON/DIN ratio in deposition and soil solution. Though, the recovery rates varied among the plots. In the two beech plots NO_3^--leaching decreased rapidly around 2004. Coniferous plots showed a more gradual recovery, with actual NO_3^--concentrations below 2 mg N l^{-1} in the deeper mineral soil during most part of the year. Only the mixed oak-beech plot remained highly N saturated, probably due to elevated humus desintegration in the mineral topsoil. This study points out that chemical recovery of forest soil solution could also be expected under high N deposition, and that NO_3^--leaching may cease rapidly when the retention capacity of the forest ecosystem is no longer exceeded.

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