**Root growth and turnover in different aged ponderosa pine stands in Oregon, USA**

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The impacts of pollution and climate change on soil carbon dynamics are poorly understood, in part due to a lack of information regarding root production and turnover in natural ecosystems. In order to examine how root dynamics change with stand age in ponderosa pine forests (*Pinus ponderosa* Laws.), we installed more than 80 root minirhizotron tubes at two sites, one with 18 yr old (young trees) and one with 60 (intermediate-age trees) and > 250 yr old trees (old trees). The goal was to determine if root distribution, production and turnover varied with tree age. The sites examined are part of the Ameriflux network of sites.

Estimates of standing crop over the 4 year study were greatest around young trees and least around intermediate-aged trees. Root production was highly synchronized in all age-classes, showing a single peak in late May-early June each year. There was no indication of a late season peak in root production in ponderosa pine, refuting an apparent misconception that conifers exhibit a flush of root growth in the fall. Rates of root turnover did show summer and fall peaks in two of the four years (late June-July and again in October). Root production and turnover were proportional to standing root crop (biomass), suggesting that allocation to new root growth was proportional to root density regardless of tree age. During the last 3 yrs the average turnover index (proportion of standing crop turned over each year) was 0.83, 0.87 and 0.62 in young, intermediate and old trees, respectively, resulting in increased standing crop over the study in all age classes. It appears that young ponderosa pine stands have greater rates of root production than older stands, but also lose more each year through root turnover. The results indicate that soil carbon accumulates faster in young than old ponderosa pine stands.

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**Trend in ambient ozone and an attempt to detect its effect on biota in forest ecosystem. Step I of Lithuanian studies**

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Ambient ozone (O3) has been recognized as major phytotoxic agent from North America to Europe since 1980s. This toxicant may reinforce the negative effect of air pollution (SO2 and NOx), and drought, what makes the estimation of its effects on biota very subtle and elusive. Long-term studies on pollution compounds and their effect on biota in forest ecosystem allow to get more insight in this relationship. The presented study aimed to explore the relationships between pollutants and tree defoliation, specific diversity of soil micro arthropods, stream invertebrates, small mammals (rodents), and on the basis of the obtained results to assess O3 effect on forest ecosystems. The investigations have been carried out since 1994 on 3 Integrated monitoring stations.

In Lithuania mean annual value of ambient O3 fluctuated between 80 and 60 μg/m$^3$, and the highest value at the level of 150 μg/m$^3$. Over the 13 year period the change in averaged monthly values was not significant, whereas the monthly maximum values decreased. Significant correlations were only detected between the highest O3 concentrations and investigated parameters of biota. Tree foliage and diversity of pedobionts were found to be the most sensitive to ozone effect. Correlation coefficient between the highest value of ozone and pine as well as birch defoliation made 0.47-0.55 ($p<0.05$). The impact of ozone on spruce trees was lower and not significant ($r=0.35$). *Oribatidas* were the most sensitive among pedobionts ($r=0.7$; $p<0.05$). Sensitivity of the other arthropods *Collembolas, Acaridias* and *Gamasinas* was lower and correlation coefficient made $r=0.4$ when $p<0.05$.

The least significant negative effect of ozone was detected on small rodents. This effect most likely could be explained first of all by effect of ozone on plants, i.e., on the main nutrition sources, although the direct effect is also possible.

No significant relationships were detected between ozone and benthic diversity. Estimated trends in benthic diversity correlated well with the changes in acidity of stream water as well as precipitation and atmospheric pollution by $SO_2$ or $SO_4^{2-}$.

In general the changes in diversity of different components of biota could be related to changes in ozone concentration, although its level was lower than phytotoxic. The obtained data indicated that Scots pine is one of the most sensitive species to detect the effect of ambient ozone. This species is prevailing in Lithuania and its condition has been monitored for already 13 years. Therefore, in our further study we concentrated on detection of the key factors contributing to changes in pine defoliation, questioning if ambient ozone reinforces the negative effect of air pollution on pine defoliation and drought on stem increment on territories under regional pollution.

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**Trends in main transboundary pollutants, meteorological conditions and Scots pine defoliation: long term study of key factors of changes in defoliation. Step II of Lithuanian studies.**

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Long range transboundary pollution and environmental acidification were implicated as major causes of forest decline on a regional scale in Europe. Unfavourable climatic conditions had negative effect on tree crown defoliation. However, recently many of the authors have revealed the negative effect of ozone which might reinforce the phytotoxic effects of other pollutants, especially SO2 and NOx as well as drought. The results of our earlier investigation indicated significant effect of ozone on Scots pine defoliation in forest ecosystem. Data from long term studies were used to estimate main tendencies in changes in acid deposition, ozone, main meteorological parameters, and Scots pine crown defoliation. The study aimed to explore if O3 may enhance the phytotoxic effects of other air pollutants, especially SO2 and NOx, on pine crown defoliation in natural condition. Multiregression analysis was used in this attempt.

Air pollution, acid deposition and meteorological parameters have been continuously monitored at Integrated Monitoring Stations established in 3 landscape types of Lithuania since 1994. ICP-Forest methodology was used to assess crown defoliation of more than 6000 trees from 48 stands annually.

$O_3$, $SO_2$ concentration in the air, $SO_4^{2-}$ and $NH_4^+$ deposition as well as precipitation of winter and summer, mean temperature of winter and spring were shown to be the key stress factors affecting defoliation of Scots pine trees accounting for up to 80% of the variation in pine defoliation. Acidifying compounds were the most relevant environmental stresses accounting for up to 64% of pine defoliation variance. The effects of $SO_2$ and $O_3$ concentration were the most significant ($p<0.0001$) among all investigated pollutants in the air. The effect of NOx and $NH_4^+$ was lower ($p<0.005$). Despite very high significance, concentration of the ambient ozone accounted for only up to 10% of pine crown defoliation changes, whereas concentration of $SO_2$ up to 40%. Generally we could state that ambient concentration of O3 reinforces the negative effect of $SO_2$ concentration on pine condition, whereas we were not a success in detecting this on drought effect. Further investigation in this field should allow to test this hypothesis more reliably.

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**Does the surface ozone affect the radial increment of Scots pine (*Pinus sylvestris* L.) on territories under regional pollution load?**
**Step III of Lithuanian studies**

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The relationships between atmospheric pollutants and tree growth have been extensively documented, however, strong evidence is rare and causal relationships are difficult to detect despite sophisticated approaches. First of all, biomass of leaves/needles (crown defoliation) results in increment changes. Tree parameters and age have an additional effect, with their increase the increment decreases. Therefore, the presented study aimed to explain the relationship between air pollution ($O_3$ and acidifying compounds) and the residual of stem squares increment of dominant pine trees when the impact of tree dendrometric parameters (age, diameter) and crown defoliation are accounted. Impact of the later was accounted due to the elimination of the direct impact of pollutants on tree crown in order to avoid double effect of pollution on trees.

Radial increment of 200 trees from 12 pine stands, where crown defoliation has been assessed since 1994 were used to achieve the objectives. Stands are located on territories of 3 Integrated Monitoring Stations where environmental pollution and climatic conditions have been monitored since 1994. Active sampler methodology was used for air pollution monitoring. Pollution variables used in the analysis included average and maximum concentrations of $O_3$, averaged values of $NO_3^-$, $NH_4^+$, $SO_4^{2-}$,$SO_2$ in the air, and $NO_3^-$, $NH_4^+$, $SO_4^{2-}$ in precipitation, and their deposition within the region. Meteorological parameters included mean temperature and amount of precipitation of the aggregated months of the seasons.

Results of our earlier study indicated that the key factor contributing to changes in pine defoliation is $SO_2$. $O_3$ only reinforces this effect. Crown defoliation, tree diameter and age accounted for 80% of the variation in increment. When the effect of these parameters was accounted, correlation analysis between residual of increment and pollution variable as well as meteorological variables revealed the highest significance of the ozone effect ($p<0.001$). Other parameters of pollution had no significance to residual changes. Significance of meteorological parameters especially precipitation was lower than that of $O_3$ and made about $p<0.01$. Integrated impact of $O_3$ and amount of precipitation over the winter season increased determination coefficient by 7% up to 86% what confirmed that ambient ozone, concentration of which did not exceed the level of toxicity reinforced negative water stress and reduced growth in larger trees affecting metabolic processes.

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# Rising atmospheric $CO_2$ and carbon sequestration in forests

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Rising $CO_2$ concentrations in the atmosphere could alter Earth's climate system, but it is thought that higher concentrations may improve plant growth through a process known as the "fertilization effect". Forests are an important part of the planet's carbon cycle, and sequester a substantial amount of the $CO_2$ released into the atmosphere by human activities. Many people believe that the amount of carbon that forests sequester will increase as $CO_2$ concentrations rise. An increasing body of research suggests, however, that the fertilization effect is limited by nutrients and air pollution, in addition to the well documented limitations posed by temperature and precipitation. We suggest that existing forests are not likely to increase sequestration as atmospheric $CO_2$ increases. Therefore, it is imperative that we manage forests to maximize carbon retention in above- and belowground biomass and conserve soil carbon.

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**Differences in the structural reactions of leaves exposed to elevated levels of controlled versus ambient ozone in *Fraxinus ornus***

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Validating the effects of ambient ozone in the leaves with experimental exposure in controlled conditions is generally complicated by the varying reactions of plants to differing environmental conditions and plant age. In this study, structural reactions of two year old seedlings treated in fumigation chambers were compared to those in leaves collected from mature trees in the field. Seedling leaves were sampled after a 7 week exposure to charcoal-filtered air vs. 150 ppb ozone during 8 h per day (AOT40 = 43.1 ppm h) in closed chambers with a low supply of light (PPFD = 500 µmol $m^{-2}$ $s^{-1}$). The ozone treated samples showed 20 % of their leaf area with ozone-induced symptoms. Asymptomatic and symptomatic (20-35 % of leaf area) leaves were sampled in September 2004 from the top and light-exposed crown of four mature trees growing in the field (Settignano, Florence, Italy; AOT40 = 21.3 ppm h in 2004). The leaf samples were immediately fixed upon sampling prior to processing in the lab in view of the planned analyzes in transmitted and fluorescent light microscopy. The morphology of leaves in seedlings showed some juvenile and shade leaf characteristics whereas that in mature trees was typical for leaves grown in full sunlight and collected at the end of the vegetation season. An ozone-induced stippling was found in leaves of seedlings and was underlain with dead and collapsed cells showing little disruption of the cell content; these structural changes signaled rapid HR-like reactions and were not distributed along gradients of light exposure. Leaves from the field showed bronzing caused by light-dependent gradients of stress reactions and accumulations of phenolic defense compounds at the cell and tissue level; these alterations indicated an accelerated senescence process due to synergic effects between light and ozone stress. Both seedlings and mature trees thus developed typical ozone symptoms in their leaves but not with the same combination of ozone stress markers. Light stress, a lower ozone dose and cumulative effects during longer exposure strongly contributed to differentiate the symptom expression in mature vs. juvenile trees. In conclusion, this study documents the plasticity of the leaf reactions in *Fraxinus ornus* and shows its dependency on the ozone exposure, environmental conditions and plant maturity.

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**Investigations on the response of sucrose and starch concentrations in leaves of adult *Fagus sylvatica* (L.) to a chronic free-air $O_3$ exposure**

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Investigations on sucrose and starch contents in leaves of about 60-year-old beech trees (*Fagus sylvatica* L.) are in the focus of the present study. Five trees were exposed to a twice ambient ozone regime ($2xO_3$) with a free-air canopy exposure system throughout the growing seasons, five trees under the prevailing ambient ozone regime served as controls ($1xO_3$).

In order to examine chronic ozone ($O_3$) effects, leaf samples from the sun and shade crown of the trees were analyzed five times throughout the growing seasons in 2003 and 2004. The year 2003 was characterized by an exceptional drought during the growing season, whereas the growing season of 2004 reflected the long-term average of the climatic conditions at the study site.

Sucrose concentrations of leaves collected in 2004 were consistently lower than those taken in 2003, regardless of the $O_3$ treatment and crown position. However, the opposite was found for starch. $O_3$ caused a reduction of sucrose and starch contents of sun leaves in both years.

Due to the fact that $O_3$-responsiveness depends on the $O_3$ uptake through stomata during the season, all carbohydrate data were related to the cumulative $O_3$ uptake (COU).

Little differences were found comparing sucrose and starch contents in leaves of trees grown under ambient or elevated $O_3$ regimes, possibly indicating the high capacity of leaves of adult beech to cope with rising $O_3$ exposure. Even under $2xO_3$, leaves were still able to regulate the $O_3$ intake by narrowing their stomata at the cost of $CO_2$-uptake and sugar synthesis. In order to clarify whole-tree response patterns carbohydrate data were compared with photosynthesis, stomatal conductance and electron transport rates. In 2004 all parameters revealed a significant common response pattern to COU that indicated a reduction for all parameters under $2xO_3$.

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**Is the Simple Mass Balance Model a realistic estimate of nutrient N critical load for the San Bernardino mountains in southern California?**

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The steady-state Simple Mass Balance (SMB) model has been widely used in Europe and more recently in other regions to estimate critical loads (CL) for acidity and N as a nutrient. However little work has examined the validity of the model in forests with a Mediterranean climate such as that in southern California. In this paper, we will compare CL for nutrient N using the SMB model to empirical CL determined from 8 mixed conifer forest sites in the San Bernardino Mountains spanning a range of atmospheric deposition inputs. Empirical CL values will be ascertained by evaluating the relationship between annual throughfall deposition inputs and soil and foliar indicators of N fertility status. Indicators of N status to be used include relative net nitrification of mineral soil and humus (percent mineralized N that is nitrified), extractable soil nitrate and ammonium, foliar N:P ratios, soil C:N ratios and foliar $\delta^{15}N$ natural abundance will be compared between the sites in an effort to estimate critical nutrient N load within the Forest. These data will then be compared to the estimate of nutrient N critical load from the SBM model, which will not include the effects of forest fire nor forest harvesting.

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**A multiple-year time-series of defence compound patterns in spruce needles and their potential relationship to meteorological conditions, site factors, and ozone exposure**

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Antioxidative compounds and photo-protective pigments are involved in defence and resistance of trees to environmental stressors, such as unfavourable climatic conditions or pollution impact. Hence, the measurement of these compounds is useful to assess forest health in particular in response to air pollution or climate change. Typical multivariate patterns of water- and lipid-soluble antioxidants and photosynthetic pigments are related to environmental combinations of site factors, climate, and pollution impact. Because of the often confounding impacts of different environmental factors, it is difficult to identify a robust relationship between defence compounds and particular stressors in field studies. A lack of long-term field studies including widely contrasting sites has significantly hindered progress in this field so far.

In the present study we investigated defence compounds in Norway spruce (*Picea abies* [L.] Karst.) needles at a number of sites at two climatically contrasting altitude profiles on limestone, one in Western Austria in North-Tyrol („Achenkirch“) and one in the southernmost part of Austria (Carinthia, „Bodental“). Trees at these sites were sampled over a time-series of 4 (5) meteorologically very different years (2001[2000]-2004), which include the Europe-wide drought year of 2003. Ozone measurements showed that the relevant AOT40 values greatly differed between years and regions. Hence, this experimental design allows us to study the potentially unique relationship of defence compounds with environmental factors including ozone exposures.

We analysed the water-soluble redox pairs ascorbate/dehydroascorbate and glutathione/ glutathione-disulfide, the lipophilic antioxidant α-tocopherol, and the chloroplast pigments lutein, neoxanthin, the xanthophyll cycle, α-carotene, β-carotene, and chlorophyll a and b. Principal component analysis was used to extract consistent patterns from this data-set and identify accumulated variables representing such patterns. The resulting principal component solution is very similar to those found in previous studies on pine and spruce in different ecosystems and confirms consistent patterns in the responses of the biochemical defence systems.

The resulting principal components are subsequently analysed for their unique relationships with site parameters, meteorological conditions, and ozone exposure to identify potential stress-physiological “indicators“ for these environmental factors.

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**Ozone-induced oxidative burst in Populus nigra and Fagus sylvatica leaves. Ultrastructural and physiological aspects.**

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The effects of ozone on *Populus nigra* and *Fagus sylvatica* leaves were investigated at ultrastructural and physiological level, within an open-top chamber experiment conducted at the Curno facilities site (North Italy (Lat. 45°41'00" N, Long. 9°37'00" E, elevation 245 m a.s.l.). The two species showed different foliar responses. *P. nigra* is a typical hypersensitive species (HR = Hypersensitive Response), in which the visible symptoms correspond to palisade cell collapse. In *F. sylvatica* an oxidative degeneration of the cell content occurred, particularly noticeable on the upper part of the mesophyll palisade cells, thus conferring a bronzing aspect to the adaxial leaf surface. Cell degeneration has been evidenced, with Evans blue staining, before visible symptom appearance. The foliar symptoms corresponded, in *F. sylvatica*, to the decrease of all the fluorescent compounds, first of all chlorophyll.

The oxidative burst, i.e. the sudden increase of hydrogen peroxide ($H_2O_2$) content in the apoplast, was shown by Cerium Chloride staining. In both species, $H_2O_2$ accumulation was detected early in the growing season, before the onset of visible symptoms. $H_2O_2$ level raised through the season in *P. nigra* leaves, whereas in *F. sylvatica* at July was no longer detectable. That was possibly due to the presence of electron-dense material in *F. sylvatica* cell walls that masked $H_2O_2$ reaction with Cerium.

Symptom intensity was related to the decrease of chlorophyll content, as a consequence of either cell disruption (especially in *P. nigra*) and chloroplast degeneration in still living cells (in both species). Chloroplast degeneration was reflected to the decrease of the chlorophyll *a* (Chl *a*) efficiency, expressed by the JIP-test parameters (derived from the analysis of the chlorophyll fluorescence transient), especially the Performance Index ($PI_{ABS}$) and the trapping capacity ($\varphi P_0 = F_V/F_M$).

In the light of these results it seems that *F sylvatica* is less sensitive to ozone than *P. nigra* because it is able to activate chemical and physiological defenses against oxidative stress more efficiently and/or rapidly.

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**Ecological stability classification system usable for evaluation of impact of anthropogenic effects on forest ecosystems**

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The methodology and procedure for the evaluation of a forest ecosystem's ecological stability and biodiversity (at the level of species and structural diversity of higher plants) is described. Attention is focussed on the temporal and spatial components of ecological stability as well as the relationships between biodiversity and ecological stability. Definitions are given of: ecosystem ecological equilibrium and organism health as state variables, and ecosystem ecological stability and organism vitality as the ability to compensate for both external and internal impacts without significant permanent disturbance of functional structure.

The temporal dimension is divided into short-term (10 year) and medium-term (50 year) indices of ecological stability. This is based on a valuation- classification system of total and partial ecological stability. The main indicators are: 1. species structure, 2. age structure, 3. vertical structure, 4. horizontal structure, 5. mosaic structure, 6. security of the next regeneration cycle, 7. static stability, 8. morphology and health of trees. Components of the classification system of partial ecological stability of the different indicators are graphs of the relationship between percentage reduction of partial ecological stability and the levels of the evaluated indicators of real forest ecosystems relative to an optimal forest stand.

Classification system for ecological stability is very useful instrument for classification of impact of antropogenic effect on forest ecosystems, including impact of air pollution and climate change on forest ecosystems.

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**Atmospheric modeling of nitrogen species in San Bernardino mountain, CA areas**

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The atmospheric budget of N is determined by the complex interaction of multiple processes including emissions of N species, transport and dispersion, chemical transformation, thermodynamic partitioning, and wet and dry deposition of aerosol and gas-phase N species. These processes are routinely represented as a coupled system of models designed to simulate air pollutants in ambient air. The model is evaluated by comparing model simulated concentrations of N and other trace species to ambient measurements, however, measurements of one key species, nitric acid ($HNO_3$) are rarely available for use in model evaluation. In this study, we compared model predictions to ambient monitoring data from a network of 11 monitoring sites in the San Bernardino Mountains operated by the USDA Forest Service. On the network concentrations of gaseous NO, $NO_2$, $HNO_2$, $HNO_3$, and $NH_3$ were determined with passive samplers and expressed as two-week averages from May through October 2002.

The modeling system includes a meteorology model, the Mesoscale Model version 5 (MM5, Grell et al, 1994) and an air quality model, the Community Multiscale Air Quality model (CMAQ, USEPA, 1999). Both MM5 and CMAQ are defined on a 3-dimensional grid for two domains: the US continent with 36km grid spacing domain and the 4km domain covering most state of California. An emission process system, Sparse Matrix Operator Kernel Emissions (SMOKE, Houyoux et al., 2000), is used to process different emissions models and database to represent a variety of emissions categories including: mobile sources, non-road sources, point sources, area sources (including agricultural activity), biogenic emissions, wild fires, prescribed burning and agricultural burning.

We performing air quality modeling for calendar year 2002 on two different model grids, a coarse 36 km grid and a high resolution 4 km grid. The comparison for $HNO_3$ shows that the model performed reasonably well on both 36 and 4 km grid, with the finer 4 km grid performing better. However, even the 4 km grid was not able to capture the full range of concentrations and spatial variability present in the ambient data. We believe that a finer grid resolution and better land use data might further improve the model performance. Poster will also show results of the comparisons made for other N pollutants.

The results of this research will be useful for future regional planning efforts to attain ambient air quality goals.

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**Visible foliar injury p Responses to ozone in northern and central Italian provenances of *Fraxinus excelsior* and *F. ornus***

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Tropospheric ozone ($O_3$) is regarded as one of the most widespread air pollutants. Current $O_3$ levels in Europe are potentially high enough to adversely affect forests. Tree species exhibit a wide range of $O_3$ sensitivity, even at the intra-specific level. In this study, we compared leaf visible injury and physiological responses (leaf gas exchange and chlorophyll *a* fluorescence) to high $O_3$ exposure (150 nmol $mol^{-1}$ h, 8 h per day, 35 days) of two woody-species, of the same genus, with different ecological features: the mesophilic green ash (*Fraxinus excelsior* L.) and the xerotolerant manna ash (*F. ornus* L.). While *F. excelsior* is considered an $O_3$ sensitive plant, the responses of *F. ornus* to $O_3$ have never been investigated. In order to investigate the intra-specific sensitivity to $O_3$, we also studied whether different provenances, from north and central Italy, within the two species, showed different responses to high $O_3$ exposure.

The results of visible foliar injury suggested that *F. excelsior* was more sensitive to $O_3$ than *F. ornus* and that the provenances, in both species, had no significant differences in $O_3$ sensitivity. Net photosynthesis ($P_{net}$), stomatal conductance to water vapour ($G_w$) and maximum quantum yield for primary photochemistry (Fv/Fm) decreased upon $O_3$ exposure. While no differences between species were observed in $P_{net}$ decrease, $G_w$ decline was faster in *F. excelsior* than in *F. ornus*. Furthermore, $P_{net}$ and $G_w$ of *F. ornus* were higher than those of *F. excelsior*, both in treated and control samples. Thus, the $O_3$ uptake in *F. ornus* plants was larger, in disagreement to the visible foliar injury data. This suggests that the $O_3$ sensitivity in this species may be linked to the capacity of the cell to detoxify $O_3$ products and/or to repair the $O_3$ damage. This was supported by the recovery of efficiency of PSII (Fv/Fm) in *F. ornus* treated plants after three weeks of $O_3$ exposure. The different provenances showed different responses to high $O_3$ concentrations, but the hypothesis of a geographical variation of plants' sensitivity to $O_3$ was not validated.

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**Scaling-up ozone exposure from 'found' data to the systematic network of forest condition assessment in Italy**

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Correlative studies to estimated potential effects of ozone on forests are constrained by the limited availability of ozone data on a representative set of forest sites. In Europe, large-scale models (e.g. EMEP) allow to obtain data at 50*50 km resolution: such a scale may be not suited for correlative study purposes. In this paper, ozone levels measured in Italy in preferentially selected sites (the so-called Level II sites and the sites of the air quality monitoring network, considered as 'found' data, *sensu* Overton et al., 1993) were used to estimate the exposure (in terms of AOT40) of the systematic forest condition assessment network. Measurements were carried out by automatic devices (national air quality network) and by passive sampling (Level II forest sites). AOT40 was calculated on the basis of the data collected over the 2000-2004 period. For passive sampling, AOT40 estimates were carried out according to Gerosa et al. (in press). Scaling-up was performed by different statistical (Voronoi tessellation) and geostatistical (Inverse Distance Weighting, Ordinary Kriging and co-Kriging) procedures which were tested by leave-one-out validation. The most reliable approach was used in order to derive AOT40 continuous fields from the input AOT40 point pattern. The paper will report about the results obtained.

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**Ozone flux measurements at a coastal Holm oak forests in non-ideal terrain conditions.**

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Ozone and energy fluxes have been measured by the eddy covariance technique, at a coastal Holm oak forest remote site in Tuscany (Central Italy) for one year in 2005. The measurements conditions have been complicated either by the lack of electricity on the site and by the complex orography. The forest grows on the slopes of a group of hills faced to the sea. The slope inclination angle ranged from 1% to 18%. The advective component of the flux has been subtracted by means of a wind direction dependent coordinate rotation and the remaining flux has been expressed as projected forest area. This resulted in a relatively simple method to obtain reliable flux information in slope conditions.

Ozone fluxes have been then partitioned in stomatal and non-stomatal ozone deposition by mean of a resistive analysis based on water and energy flux measurements. Preliminary results showed that the highest observed ozone flux value was 36.6 nmol $m^{-2}$ $s^{-1}$. The ozone fluxes mean daily course showed a fast increase of oze deposition in the first hours of the morning, as the turbulence raised up enhanced by the incoming solar radiation. Turbulence characterized deposition in the central hours of the day, with a quite irregular shape in the ozone fluxes until 18 when they quickly decreased. In the central part of the day ozone fluxes values ranged between 6 and 10 nmol $m^{-2}$ $s^{-1}$. The mean value of the ozone fluxes in the considered period was 4.65 nmol $m^{-2}$ $s^{-1}$.

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**Seasonal variations of ozone exposure and fluxes in a Mediterranean Holm oak forest during two seasonal field campaigns**

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Ozone and energy fluxes have been measured, using the eddy covariance technique, for five months in 2003 (from August to December) and seven months in 2004 (from June to December) at the Castelporziano Holm oak forest, a typical Mediterranean ecosystem located 20 km far from the city of Rome (Italy). Stomatal fluxes had been calculated using a resistance analogy and the inversion of the Penmann-Monteith equation. Results showed that the average stomatal contribution accounts for 42.6% of the total fluxes. Non-stomatal deposition was the most relevant sink for tropospheric ozone and it was enhanced by the leaf wetness, which increased its influence during the autumnal months. Another substantial ozone sink was also represented by anthropogenic nitrogen oxides emitted from the near city of Rome, particularly in the first hours of the morning.

A comparison between the two years measurements highlighted some interesting correlations between ozone exposure, expressed as AOT40, and ozone dose taken up by the Holm Oak forest. During summer, when water availability was the most important limiting factor for the ozone uptake, AOT40 and stomatal flux were closely correlated and began to diverge only in autumn when there was an increase of rainfall events and ozone concentration decreased in relation to the less intense solar radiation.

The results suggested a simple way to estimate the summer ozone uptake of the forest, starting from the seasonal ozone concentration mean and the seasonal mean of the stomatal conductance to ozone.

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**Visible and microscopical symptoms of ozone stress in leaves of European beech**

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Visible and microscopic symptoms in leaves of European beech (*Fagus sylvatica* L.) trees under experimental or ambient ozone ($O_3$) exposure were compared using material from several experiments including A) a climate chamber experiment with 50 % ambient vs. 50 % ambient + 30 nll-1 $O_3$ with the fumigation starting before bud break; B) the same experiment but in partially shaded OTCs; C) ambient $O_3$ vs. filtered air in OTCs; D) ambient and 2 x ambient $O_3$ within the CASIROZ free air fumigation-experiment (FACE) in a mature beech stand at Kranzberger Forest in south-eastern Germany; E) field samples from mature beech trees sampled in south-eastern Germany, France and Switzerland. In A and B, shade leaves (one layer of palisade cells only) under experimentally doubled $O_3$ concentration first showed light-green interveinal discoloration at the upper leaf side which developed into necrotic stippling and eventually necrotic areas after 1 – 2 months of exposure (AOT40 = 9 ppmh). Some samples from the FACE experiment (D) showed acute and convergent stippling. For the samples from C) and E), visible leaf symptoms particularly developed in leaves and leaf parts exposed to full sunlight in the form of interveinal gradients of chlorophyll bleaching and bronzing leading to a progressive discoloration of the leaves with stippling and necrotic areas in some cases.

Structural changes triggered by $O_3$ stress were analyzed by transmitted and fluorescent light microscopy (using metachromatic or specific stains) and transmitted electron microscopy. Leaf discoloration, in the form of light-green spots, chlorophyll bleaching and bronzing, related to accelerated cell senescence. The former symptoms were caused by changes in the chloroplast structure (degeneration showed by large electron-light plastoglobuli, disappearance of grana and condensation of stroma) and the latter by the accumulation of condensed tannins. Together with nucleus condensation and increase in the vacuome size, these symptoms progressively increased in palisade cells with a higher light exposure. Ozone-induced stippling was related to hypersensitive-like responses in the upper palisade cells: groups of necrotic and partly collapsed cells showed disruption of the cell content and condensation and oxidation of the cell remnants to apoptotic-like bodies. Oxidative stress was shown by gradients of oxidation of tannins, chloroplastic injury or irregular cell wall thickening especially in the more light-exposed cell portions of the palisade tissue.

Changes in cell and tissue physiology triggered by $O_3$ stress showed not only similarities, whatever the treatment or field conditions, but also differences in particular associated with the light and $O_3$ stress intensity. They all originate in the mesophyll where the variability of changes eventually determines that at the whole leaf level. The leaf symptom plasticity needs to be taken into account for ozone threshold definitions.

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**Foliar gas exchange, biomass production and heavy-metal uptake of young deciduous and coniferous trees grown on contaminated soils**

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Gas exchange, biomass production as well as heavy-metal (Zn, Cu) uptake and allocation of young trees (*Populus tremula, Salix viminalis, Picea abies*) were analysed in a 3-year study. The trees grew in mixed stands in lysimeters ("model ecosystems") with metal-contaminated topsoil (Zn/Cu/Pb/Cd = 3000/640/90/10 mg $kg^{-1}$) and uncontaminated topsoil. Other factors varied were the type of subsoil (calcareous vs. acidic) and the acidity (pH 3.5 vs. 5.5) of the (synthetic) rainwater. Hypotheses were (1) that the photosynthetic capacity of *P. tremula* and *S. viminalis* is negatively affected by the contamination; (2) that increased Zn and Cu decrease the biomass production of *P. tremula* and *S. viminalis*; (3) that a negative influence of Zn and Cu on the biomass production is more pronounced on acidic than calcareous subsoil; (4) that *S. viminalis* has the highest potential for phytorextraction of the three tree species compared; (5) that *P. abies* has the lowest metal uptake into aboveground plant parts and therefore no effects on photosynthesis and biomass production.

The production of foliage and wood and also the photosynthetic capacity were significantly reduced by the metal treatment in *P. tremula* in the third year. *P. abies* showed no difference to the controls in any year. The biomass of *S. viminalis* was significantly reduced in the third year on acidic, but not so on calcareous subsoil. Negative effects in *P. tremula* were related to Zn concentrations in leaves and wood which exceeded toxicity thresholds. Zn uptake by *P. abies* and *S. viminalis* did not lead to a negative effect on photosynthesis or biomass. Cu accumulated in the wood of trees grown on acidic rather than calcareous subsoil, whereas Zn was mainly allocated in the leaves. Effects of the acid rain treatment were negligible. Concentrations of Cd and Pb in above-ground plant parts were near the detection limits of Cd (0.6 mg $kg^{-1}$) and Pb (3.0 mg $kg^{-1}$).

The effects on *P. tremula* agreed with hypothesis (1) and (2), in contrast to *S. viminalis*. The effects on either of the two deciduous tree species did not agree with hypothesis (3). In agreement with hypotheses (4) *S. viminalis* appeared to be best suited for phytoextraction purposes. This latter species was similarly metal tolerant as *P. abies*. In agreement with hypothesis (5) *P. abies* showed a slow biomass production and low heavy-metal uptake.

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**Heavy metal accumulation in back ground forest soils due to long range transported atmospheric deposition.**

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The change in heavy metal content in forest top soils (0-10 cm) over a period of 45 years is presented. The heavy metal content was determined in soil samples from an archive consisting of more than 400 soil samples collected in 1961-1963 in Denmark and samples collected during 1974 and 2006. The sampling of forest soils 1974 and 2006 was carried out at 50 of the original collection sites.

The atmospheric deposition of heavy metals was estimated from 30 years of measurements of bulk precipitation at 8 forest sites. Dry deposition of heavy metals was estimated from measurements of heavy metals in aerosols from 4 forest sites during 15 years at one station more than 25 years. The total atmospheric input to the forest ecosystem was calculated from bulk precipitation measurements and dry deposition estimates.

The accumulated atmospheric input during 1976 to 2006 of heavy metals to the forests was compared to changes from 1961 to 2006 of the heavy metal content of the forest top soil.

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**Soil $CO_2$ efflux in a mixed pine-oak forest in Valsaín (Central, Spain)**

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Isolated populations from marginal sites of the forest species distribution area, ecotones and transitions between systems may loss biodiversity as a consequence of climatic changes and urban development. A lack in the natural regeneration of South-western Scots pine (*Pinus sylvestris* L.) stands that has been gradually replaced by the broadleaved *Quercus pyrenaica* Lam, have been detected in Spain during the last century. Furthermore, climate change is projected to decrease precipitation and increase temperature in this area. The interaction of these environmental factors may change the carbon balance of these Mediterranean forest ecosystems and the relative abundance of these species. Soil respiration (SR) provides the main carbon efflux from terrestrial ecosystems to the atmosphere. Global warming and changes in rainfall amount and distribution may affect soil respiration and will contribute to the increase in $CO_2$ concentration in the atmosphere. However, little is known about the relationship between diversity and soil $CO_2$ efflux. With this in mind we started an experiment to investigate the site and time variation in soil respiration in a pine-oak stand at Valsaín Forest in the north face of Sierra de Guadarrama (Segovia, Spain). A transect around the ecotone between *Pinus sylvestris* L. and *Quercus pyrenaica* forest stands have been established in 2005. Three representative forest plots with radio of 25 m were selected, under *Quercus pyrenaica* (Q), *Pinus sylvestris* (P) and *Quercus pyrenaica-Pinus sylvestris* (QP). Soil $CO_2$ fluxes were measured at each site with a closed dynamic system (LI-COR 6400) using soil collars. To identify additional physical and biotic influences on soil $CO_2$ efflux, we measured soil moisture, soil temperature, Walkey-Black C (CW-B), total soil organic matter (SOM), particulate organic matter (POM), organic matter fraction bellow 53 μm (OM<53), total soil nitrogen content and tree density in each site. Preliminary results show the strongest relationship between soil temperature and $CO_2$ efflux when soil moisture was above the drought threshold. Greater SOM, POM and CW-B in P compared to Q sites potentially contributed to the greater total soil $CO_2$ efflux in these stands. Further, opposing trends of OM<53 and SR between plots suggest that in Q stands the C forms are more stable to possible changes in use.

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**Risk assessment of ozone effect on *Pinus densiflora* and *Fagus crenata* in Japan**

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Daytime annual mean AOT40 of surface ozone in Japan was 4.0 ppm-h in 1981 with gradually increase and it reached at 12.8 ppm-h in 2003. *Pinus densiflora* is a widely distributed species from low elevation areas to mountains in the nation and *Fagus crenata* is a representative deciduous tree species. Both are representative very sensitive species to $O_3$ in our exposure experiments. We have conducted nationwide overlay analysis of distribution of both species and ambient air quality to estimate surface ozone impact on both species.

Assuming that results of exposure experiments conducted in juvenile seedlings for 2 to 3 years would be applicable to those of mature trees, we estimated critical levels of $O_3$ inducing 10 % growth reduction. It would be 17 ppm-h as AOT40 under the radiation at and over 50W/$m^2$ for 6 months for both species. Distribution of 5-year mean of AOT40 suggested that areas over this critical level expanded and both forest stands would have increased potential risk of $O_3$. Our survey suggested that forest stands at high elevation sites showed higher dose of $O_3$ than that of current calculation. Thus our temporal risk assessment could be underestimated.

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**Dose-response relationships of photosynthesis in adult *Fagus sylvatica* under experimentally enhanced free-air $O_3$ exposure**

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Responses of photosynthesis to cumulative ozone uptake (COU) are still scarce, in particular, with respect to adult trees. This issue was examined on 60-year-old beech trees (*Fagus sylvatica*) which were exposed to the ambient ($1xO_3$) and an experimentally enhanced twice-ambient $O_3$ regime ($2xO_3$, by means of a free-air ozone canopy exposure system) at a forest site of southern Germany. $O_3$ responses of the light-saturated photosynthetic rate ($A_{max}$), stomatal conductance ($g_s$) and electron transport rate (ETR) were assessed five to seven times during the growing seasons of 2003 and 2004 each. In addition, the $O_3$ sensitivity of the maximum rate of carboxylation ($Vc_{max}$), Ribulose-1,5-bisphosphate turnover-limited rate of photosynthesis ($J_{max}$), $CO_2$ compensation point (CP), photosynthetic efficiency (PE), carboxylation efficiency (CE) and day and nighttime respiration were highlighted. The analysis covered effects of the exceptional drought in 2003.

The hypotheses were tested that (1) the above parameters are affected by $O_3$ and that (2) with rising COU the differences in response between the two $O_3$ regimes become increased.

$Vc_{max}$, $J_{max}$ and CE decreased under $2xO_3$ in relation to $1xO_3$ in the year 2004, confirming hypothesis (1). However, $Vc_{max}$ was not negatively affected during the growing season of 2003 despite high $O_3$ uptake (< 25 mmol $m^{-2}$ COU), whereas in 2004 $Vc_{max}$ was already significantly lower by $2xO_3$ per se at 20 mmol $m^{-2}$ COU. Furthermore, COU decreased $A_{max}$, $g_s$ and ETR under $2xO_3$ in relation to $1xO_3$ consecutively over the season in 2004. Nevertheless, hypothesis (2) was rejected because differences in $A_{max}$, $g_s$ and ETR between the two ozone regimes were lower at the end of the dry summer 2003 as compared to the preceding assessments in the same year.

The presented dose-response relationships of photosynthesis are not consistent across the two examined years, this may be an indication of an altered defense capacity which is not only dependent on $O_3$ but also on climatic conditions. Although leaf-level parameters proofed to be sensitive to high COU, photosynthetic limitation was minor so that ozone stress was apparently compensated for within the crown before measurably curtailing stem production.

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**Chemometric study of bulk precipitation and throughfall in different age of spruce stands on Potok Dupnianski catchment within 1999-2003 (Silesian Beskid – southern Poland)**

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Cycling of elements in spruce stands, which are affected by industrial emissions, is still subject to numerous studies. The retention of considerable volumes of contaminants by the canopy and their removal or washout from needles by rainfall cause changes in the concentration of anions and cations reaching the soil surface. In the present study changes in the concentration of anions and cations ($Cl^-$, $NO_3^-$, $SO_4^{2-}$, $NH_4^+$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Fe^{2+}$, $Mn^{2+}$ and $Zn^{2+}$) in bulk precipitation and throughfall in spruce stands of different age classes ($1^{st}$, $2^{nd}$, $5^{th}$ and $6^{th}$) on the Potok Dupniański catchment in the Sileasian Beskid within 1999-2003 were examined and chemometrically evaluated. A key objectives was to analyse the correlation between inorganic anions and cations in bulk precipitation (BP) and throughfall taking consideration age of the spruce stands, to assess trends in the behaviour of pollutants and seasonal effects of the pollutants concentration, to detect of latent factors which could be interpreted as anthropogenic or natural sources responsible for the chemical content of the environmental samples. Three multivariate techniques (time series, principal component analysis and analysis of variance) were applied in this study to achieve defined objectives.

In bulk precipitation as well as in through fall it was found a significance statistical correlation between anions of strong acids $NO_3^-$ and $SO_4^{2-}$ as well as between them and macronutrients (Ca, Mg, Na and K). In through fall anions of strong acids may effect on release of K and Mn from the spruce crown in young stands and other cations like Na, Mg and Ca from the older one due to the high significant correlations between them and chemical reaction were washed out from needles and/or the bark as well as decrease of water reaction. The time series trends of major anthropogenic pollutants indicate occurrence of decreasing trend what is in agreement with polish long-term reduction of $SO_2$ and $NO_x$ emission as well as basic cations. This trend in near future can negative effect on forest ecosystems. The application of principal component analysis has led to identification in general of four latent factors responsible for the data structure ("mineral dust", "anthropogenic" and "heavy metals-dust particles" and "ammonia"). The number of factors for both sites is the same and the content and the meaning of them is almost identical, they explain more than 60% of the total variance system. Multiway ANOVA proved that chemical composition of throughfall water depends on the age of the spruce stands (effective crown area). The strong positive correlation occurs both for all year and winter period for major anions belonging to "anthropogenic" factor: $SO_4^{2-}$+$NO_3^-$; to "heavy metals-dust particles": $Fe^{2+}$+$Mn^{2+}$+$Zn^{2+}$; "mineral dust": $Na^+$+$K^+$+$Ca^{2+}$+$Mg^{2+}$, "ammonia" and $H^+$. The strength of the relationship decreases in the vegetation period due probable modification by the processes occurring in canopy (adsorption, leaching, etc.).

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**Impact of greenhouse gases on epicuticular waxes of *Populus tremuloides, Accer saccharum, Betula papyrifera*: results from an open-air exposure and a natural $O_3$ gradient**

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Epicuticular waxes of three trembling aspen (*Populus tremuloides* Michx.) clones differing in $O_3$ tolerance, of sugar maple (*Acer saccharum*) and paper birch *(Betula papyrifera)* were examined for six growing seasons (1998/2003) at three localities in a "natural" $O_3$ gradient from Rhinelander, northern Wisconsin (background $O_3$, 1996 SUM00 = 41.0 ppmh), to Kenosha, southern Wisconsin (high $O_3$, 1996 SUM00=70.4 ppmh) to Kalamazoo, southern Michigan (low $O_3$, 1996 SUM00=47.3 ppmh). Differences in epicuticular wax structure were determined by scanning electron microscopy and quantified by a coefficient of occlusion. Statistically significant increases in stomatal occlusion occurred for the three $O_3$ bioindicator sites as we predicted with the higher $O_3$ sites having the most affected stomata for all three clones and also in birch and maple leaves as well as for all treatments including elevated $CO_2$, elevated $O_3$, and elevated $CO_2$+ $O_3$. The results suggest that $O_3$ pollution of the Kenosha and Kalamazoo sites show significant negative impact on epicuticular waxes of aspen and these impacts are the most severe on the most $O_3$ sensitive clones. We recorded statistically significant differences between aspen clones, sampling period (spring, summer, fall) and localities Rhinelander, Kalamazoo and Kenosha. We found statistically significant differences between treatments and aspen clones in rust frequency.

Chemical analyse show differences in the concentrations of Al, As,Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Eu, Fe, K, La, Mg, Mn, Mo, N, Na, Ni, Pb, Rb, $S_{total}$, $S_{org.}$, Sb, Sc, Sm, Sr, Tb, Th, W, and Zn in the foliage of 3 aspen clones from 3 localities and 4 treatments, and also in birch and maple leaves from Rhinelander. Nutrition ratio S/N was disturbed in all observed tree species, when compared with limit range. Our results showed that capability of sulphur to increase exceeded in all cases the need of plants regarding protein synthesis. Finding of high values of S in aspen leaves in Rhinelander, despite the absence of the source of $SO_2$ emission is surprising. This increase can be explained by the uptake of $SO_2$ emission from long-range transfer in the form of wet fallout. Foliage surface of three aspen clones contained Al, Si, Ca, Fe, Mg, K, Cl, Mn, Na, Ni, Ti in all studied localities. In the locality Rhinelander the particles containing Th and Y were found, and in Kenosha the particles contained Ba. These results and the relation of higher contents to the denser covering of the leaves with dust suggest that recently deposited adhering dust particles are responsible for the higher elemental contents measured in the leaves. In contrast to these foliage surface parameters, the epicuticular wax quality did not show any relation to the concentration of the investigated heavy metals.

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## Level II plots in Spain: atmospheric deposition years 1998-2003

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**Abstract.**

Pan-European Programme for Intensive Monitoring of Forest Ecosystems, also called Level II European grid, provides updated information about forest condition and possible influence of factors as climate, biotic agents or air pollution at global scale. It also constitute a consistent database that support European policies in climate change, forest biodiversity and sustainable management of forest, giving information at general, regional and local level.

Research activity in the level II plots comprises: visual assessment of crown condition, soil and soil solution analysis, foliar nutrient contents, forest growth and increment, atmospheric deposition, including passive sampling of air pollutants, meteorological monitoring and phenology, inventory of ground vegetation, visual Ozone injury assessment, and others studies related to biodiversity, vitality and climate change.

Main goals of the deposition measurements are to obtain an accurate knowledge about the deposition process in forest ecosystems and to give information for the mapping of critical loads. Samples obtained in throughfall and stemflow collectors supplies long series of data about pH, conductivity, base cations, several anions, alkalinity and N total. Also Al, Mn, Fe and heavy metals are analyzed. There are available data from 1997, in 15 days periods as average.

Results show the variation in the atmospheric deposition data assessed in 13 Spanish plots, ranging from wet temperate northwest forest on acid subtract (Galicia) to arid Mediterranean pure calcareous ecosystems (Alicante), from the beginning of the sampling to now. Analysis of the results links the short-term meteorological data variations, mainly rainfall and temperature, with vegetation cover, taking account quality and quantity of atmospheric deposition in several elements, studying in addition variation in time and possible trends in a possible climate change scenario.

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**Ozone deposition to forest is dynamic and correlates positive with temperature**

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At field conditions, it is difficult directly to relate ozone measurements in the air to plant responses.

Plants respond to the ozone taken up through stomata reacting chemically with plant tissues. Ozone reacting with the outer surfaces or thermally decomposed at the surfaces have other harmful potentials.

We used a simple model where the night time depositions acted as a surrogate for surface deposition at day time to identify ozone flux through the stomata's at daytime.

$O_3$ flux measurements were made from a 36-m meteorological mast placed in an experimental forest area dominated by Norway spruce. Long-term measurements were made by the gradient method from 1996 to 2003 and novel correlations between the gradient method and the eddy correlation method are reported.

The results indicate that the uptake through stomata's is smaller than previously suggested in flux based studies.

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**Foliar injury caused by exposure to ozone reduces the absorbance of light in leaves of cutleaf coneflower (*Rudbeckia laciniata var. digitata*)**

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One of the most common symptoms of ozone exposure in plants is flecking or stipple, which results from the synthesis of phenolic compounds by cells in or near the epidermis in the presence of high light. Shading can reduce or prevent stippling from developing. Although anthocyanins are commonly synthesized in response to ozone, some plants, such as the cutleaf coneflowers in this study, produce other water soluble phenolic substances that are brown in color. Coneflower leaves with brown stipple were sent to Germany and found by HPLC to contain an unusually high amount of chlorogenic acid (=caffeoyl-quinic acid; 100 mg per g leaf tissue). Dicaffeoyl-quinic acid and wall-bound caffeic acid were also detected. Caffeoyl-derivatives are known to be easily oxidized to brownish quinoid and polymeric products. However, ozone-injured coneflower leaf tissue still contained 90% of the original chlorogenic acid. This is in contrast to literature reports for leaves of Bel W3 tobacco, where ozone led to the virtual disappearance of chlorogenic acid. Eventually, pigmented cells die and cause widespread necrosis over the leaf surface. Similar pigmentation changes also result after pathogen attack, and have led to the hypothesis that ozone mimics a generalized pathogen response, because both agents result in the accumulation of toxic reactive oxygen species (ROS). Despite the widespread occurrence of pigment induction by ROS, almost nothing is known about the potential adaptive significance of stippling itself. We hypothesize that the synthesis of these phenolic pigments reduces the amount of excess light reaching the mesophyll of ozone-stressed leaves, thereby limiting production of additional ROS from photo-oxidative processes. Using a Li-Cor 1800 spectroradiometer with an integrating sphere, we show that injured leaves (>50% stipple) of cutleaf coneflower (*Rudbeckia laciniata* var. *digitata*) absorb approximately 4.8% less visible radiation, particularly in the yellow to red wavelengths (550-700 nm), due to greater reflection and transmittance when compared to non-injured leaves. This relatively small difference in absorption is unlikely to have a large protective effect against photo-oxidative processes in injured leaves, and leaves open the question of whether stipple formation following ozone exposure has any adaptive value at all.

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**Ozone sensitivity of *Fagus sylvatica* and *Viburnum lantana* seedlings grown in monoculture or in mixture**

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Seedlings of *Fagus sylvatica* (beech) and *Viburnum lantana* (Viburnum) grown in monoculture and mixture were exposed to ambient and sub-ambient (charcoal-filtered) ozone concentrations in open-top chambers over the course of two growing seasons at the Lattecaldo open-top chamber facility in southern Switzerland. The aim of the study was to determine how the sensitivity to ozone in ambient air of these two relatively different species would differ between monocultures and mixtures in terms of growth and visible foliar injury development. In general, Viburnum was a stronger competitor than beech over the course of this two-year study. Seedlings of Viburnum benefited from interspecific competition in terms of both height growth and above-ground biomass accumulation at the expense of beech seedlings, which showed significantly reduced growth in the mixture as compared to the monoculture. However, as this was only the case for Viburnum growing in the charcoal-filtered treatment, ozone seemed to counteract the beneficial effect of interspecific competition on above-ground biomass accumulation in Viburnum, while at the same time decreasing relative biomass allocation to roots. Foliar sensitivity of the two species was also altered under interspecific competition suggesting that results based on seedlings of single-species grown in monocultures may significantly over- or underestimate foliar sensitivity to ozone. These results demonstrate that competition is an important factor affecting plant responses to ozone stress, but the direction and severity of these effects depend on the interacting species. Therefore, interspecific competition should be considered when determining the ozone risk to sensitive forest species.

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**Biomass and tree-ring analysis in young trees from an open-top chamber study of the effects of tropospheric ozone**

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Seedlings of Fagus sylvatica, Quercus robur and Fraxinus excelsior were exposed to ambient ozone air pollution during three years in an open-top chamber experiment at Curno conducted at the Curno facilities site (Northern Italy) (Lat. 45°41'00" N, Long. 9°37'00" E, elevation 245 m a.s.l.). The experiment included also Populus nigra cutlings but, because of their very fast growth, they were coppiced at the end of each year. The experimental set-up included well-watered and drought-stressed plots, in order to assess the role of drought in modifying the effects of ozone stress. At the end of the experiment all plants were cut and the aboveground biomass (dry weight) was determined. In addition, the radial growth was measured by tree-ring analysis.

The ring-width data were analyzed jointly with the physiological parameters assessed through the lasting of the experiment, with special reference to the foliar content of chlorophyll, the chlorophyll a efficiency, the stomatal conductance (measured and modelled) and the ozone foliar uptake. The data-set was analyzed with ANOVA and multivariate statistical techniques.

The results suggest that the growth of the seedlings in an ozone-rich environment follows species-specific patterns. Not always tree-ring width and biomass decreased. Beside, the response can vary over the years and it needs to plan long-term experiments need.

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**Differential response of ten poplar clones to fertilization and climate effects at low groundwater table**

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The building of new river dams for electricity production resulted in severe changes of water regime in the basin of Drava River (a tributary to Danube), stretching through Italy, Austria, Slovenia, Hungary and from northwest to northeast of Croatia. Large areas of ecologically very valuable forests are exposed to the significant lowering of the groundwater table along the river derivation channels, resulting in severe dieback, growth depression and poor natural regeneration of riparian tree species, especially European black poplar (*Populus nigra* L.). The urgent need for selected genetic material adapted to specific conditions of alluvial soils with low groundwater levels is accompanied by the lack of a clear view on the future forest and environmental management of riparian ecosystems damaged by urban development. The trial of 10 poplar clones (6 *P. deltoides* clones, 2 *P. x euramericana* clones and 1 clone each of *P. nigra* and *P. alba*) was established in the year 2001 next to one of the derivation channels. In 2004 and 2005, a fertilization experiment was incorporated into the existing trial to test the response of clones to four nitrogen (N) fertilizer doses. The response of height and diameter increment percentages differed significantly among clones and N treatments, indicating insufficient, adequate or excessive N fertilization. The mass of leaves and foliar concentrations, content, and ratios of mineral elements were used to explain these differences. Climate differences between 2004 and 2005 were an additional source of variability, influencing both nutrition and growth of clones. The potential of tested poplar clones and species for use in intensively managed plantations as well as their suitability for the restoration of damaged natural stands is discussed.

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**The effects of alkaline air pollutants on selected tree species**

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The region of Jelšava - Lubeník is presented as the area with the highest and specific alkaline air pollutants and alarming degree of the environment damage in Slovakia. It represents a unique model territory for the study of the problems as well as testing the possibilities of recovery and rehabilitation of forest ecosystems.

The effect of alkaline air pollutants on the young plants of Austrian pine and European beech was studied. The experiment was carried out under controlled temperature, light and humidity conditions with simultaneous eliminating dusty magnesite fallout. The main attention was focused on impact of contaminated soils (with different degree of soil toxicity) on selected parameters of plants. The height and diameter increment, growth rate of roots, phenology of terminal buds, yellowing of needles and decline of plants were observed. The leaf area, leaf weight and electric resistance of cambial tissue were measured during the experiment, too. The foliage and soil nutrients status were determined.

Decrease of height and diameter increment and growth rate of roots with increase of soil toxicity degree were observed. The values of electric resistance of cambial tissue increased with the injury of plants. The higher degrees of soil contamination caused premature leaf and needles yellowing and consistent death of all tested plants. The plants grew in the soil with the highest degrees of soil contamination but under grass cover, (functioning as a filter) showed the higher increment and more favourable health as the plants without grass cover. This fact can be used as advantageous method of melioration in future.

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## Decline of Greek fir (*Abies cephalonica* Loudon)

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In this study, we present results from the research program Archimedes "Fir decline in Greece". Decline of Greek fir (*Abies cephalonica* Loudon) has been reported throughout Greece during the last four decades. The symptoms include crown dieback, needle discoloration and loss, death of twigs, branches or whole tree death. In years with high mortality rates, some declining trees show needle discoloration or a dead branch, usually in the middle of crown and then in 2-3 months they die. Mortality rates are usually around 5-10% but in some stands it can be almost 40%. A number of causes for the fir decline have been proposed such as drought, climatic change, air pollution and pathogens or insects. Climatic data analysis showed that drought is one of main drivers of fir mortality, because widespread mortality occurs usually after consecutive dry years, as it happened in 1963, 1977-1978, 1988-89, and more recently in 2001-02. The crown and root condition of fir trees, at different stages of decline, were assessed and the results showed that root condition was related to needle loss and crown discoloration. In another study, the root development of alive and dead trees was compared. Dead trees were characterized by a decreased portion of fine root biomass. We found no significant differences in other root variables such as total root length, number of branches and biomass of each root order. Macrofungal fruit bodies were collected from stands with different degrees of forest decline. Data indicated that fungal species diversity was higher in the least damaged stand. Furthermore, predominant species in the least damaged stand were mycorrhizal, while in the most damaged stand a majority of species were saprotrophs.

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**Ozone in the National Parks and protected forest of Spain**

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Tropospheric ozone is considered today by far the most important air pollutant toxic to plants world-wide (Krupa and Manning, 1988; Krupa et al., 2000). Reports by the European Environmental Agency (EEA, 2003, 2004a) suggest that the Mediterranean region based in ozone concentration measurements is the area at the highest ozone risk in Europe, where the highest number of exceedances of warning/alert thresholds occurred between 1995 and 2004 (EEA, 2005). Sanz et al. (2004) found for 83 south-western remote sites (France, Italy, Switzerland and Spain) ICP-Forest Intensive monitoring Plots (IMPs) that the April-September average daily ozone concentrations (2000-2001) decreased with ascending latitude and increased with increasing altitude. Such patterns were confirmed for the years 2002 and 2003, with higher concentrations in 2003, by ICP-Forest across Europe (De Vries et al 2003; Lorenz et al 2004).

In general it is difficult to measure air pollutant concentrations in remote areas, as they are most of the National Parks and Protected areas. Passive samplers provide an accurate and inexpensive method of measuring cumulative exposures of different air pollutants (Brown 1993; Kruppa, 2000; Namiesnik et al. 2005). They have been used to collect ozone data in both laboratory (Grosjean and Hisham, 1992; Koutrakis *et al*., 1993; Tang 2002) and field at different scales, form local to continental (Ray, 1993; Sanz, Sanz, & Sánchez-Peña, 2001; Bytnerowicz et al. 2002 a,b; Alonso et al 2002; Cox, 2002; Bytnerowicz et al. 2004; De Vries et al 2003; Sanz, Calatayud &, Sanchez-Peña, 2004). However, few of the studies were carried out in National Parks or Protected areas (Flores, Ray & Joseph 1996; Brace & Peterson 1998; Ray 2001; Bytnerowicz et al. 2002 a).

The objective of present study is to fill the gap on the knowledge of the air quality remote areas, like National Parks and protected areas, in Spain. Since there is no systematic data sets on main air pollutants that can affect such areas. A rural network for air quality measurements was established in 2001 in more than 30 locations sited in within the boundaries of most of the Spanish National Parks and protected areas under the supervision of the National Parks Department. Network operations were running during all the year period for 3 years, except in some cases when in winter periods the locations were not accessible due to weather extreme conditions. The sampling locations within each park or protected area were selected with the help of park field staff, based on the geographical location, accessibility, experimental design, elevation and previous knowledge, if any, of the atmospheric dynamics in the area. Data collected suggests that levels of ozone in mountainous areas are high enough to affect sensitive vegetation.

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**Effects of strong wind and ozone on tree decline in mountains**

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Tree decline has been associated with a complex system of multiple stress factors, such as air pollutants and natural stress factors. Most of forest decline in remote mountains is confined to specific areas, and have a possible linkage with meteorological factors. However, the main causes of the decline and their combined influences have not been sufficiently clarified yet. In this research, attention was paid to wind and ozone ($O_3$) those are expected to have significant influence on the localized tree decline in mountains. The computational fluid dynamics simulation (CFD) of wind and $O_3$ transport is performed in mountains.

In order to accurately predict the variation of local wind and $O_3$ caused by complex terrain, the CFD code is based on the coordinate transformation along earth surface, the high order finite difference method and the standard k-ε model. The photochemical reactions are omitted here, because the advection should be dominant in the narrow computational domains (~10x10km$^2$). The dry deposition model of $O_3$ are based on a conventional formulation and directly connected with CFD techniques.

The contour of the normalized annual mean $O_3$ advection flux at a ground height of 10m at Tanzawa mountains (Japan) was shown. Advection flux shows the amount of $O_3$ transported in parallel with the ground surface, and could be one of the evaluation indicators of the combined influence of wind and $O_3$. The result suggests that the advection flux increase near the top of mountains, and the areas with the high flux correspond well with the tree declined areas. Thus, the locality of tree decline in this region is strongly influenced by local wind and local $O_3$ transport. More detailed results to understand the mechanism of the decline phenomena will be presented in the conference.

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(Will be presented by Y. Kohno: kohno@criepi.denken.or.jp)

**Air pollution, mediterranean climate, and the San Andreas fault -- rapid forest soil acidification across an ancient landsurface, San Bernardino mountains, southern California**

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We have observed rapidly acidifying soils within southern California's San Bernardino mountains under conditions where (1) very high rates of anthropogenic atmospheric nitrogen (N) are added to the soil surface (~80 kg ha-1 yr-1) from wet, dry and fog deposition and (2) the physical character of an ancient landsurface, uplifted by tectonic activity along the San Andreas fault, limits early wet season percolation of soil solutes. Monthly neutron probe measurements of soil moisture and seasonal measurements of soil chloride (as a conservative tracer) and soil nitrate allowed the calculation of soil solute flux to depths of several meters over a two year period. These patterns were compared between two different pedological sites: one where a buried stone layer demarks the surface of the ancient landscape and a second where the stone layer is absent. Then, soil pH was measured for two similar study sites where the stone layer was present, but which differed due to their input of anthropogenic nitrogen. One site is heavily impacted by photochemical smog, and the second is protected within a 'smog shadow' due to the topography of the mountain massif. When the stone layer is present, it dramatically controls soil water movement spatially and temporally, by limiting early season infiltration carrying nitrate to the buried rock layers at the 50 to 80 cm soil depth. Under these conditions, the soil is rapidly acidifying at the high N deposition site. Here soil pH correlates with the soil concentration of nitrate and has changed from a value of ~ five measured in October 1975 to ~4.5 in October 1993 to ~3.3 in October 2003.

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