Workshop on regional impact assessment of
atmospheric deposition and air pollution on forest ecosystems
21-22 November 2019, Niigata, Japan

Workshop on regional impact assessment of atmospheric deposition and air pollution on forest ecosystems

Abstract Book

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Long-term trends of anthropogenic emissions of air pollutants in Asia

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Huge growths of emissions of air pollutants in Asia are affecting not only local air pollutions but also regional, inter-continental, and global air qualities. In addition, emissions of greenhouse gases and Short-Lived Climate Pollutants (SLCPs) in Asia are considered to have strong impacts on global climate change. On the other hand, historical trends of emissions in Asia vary with regions and are complicated especially recently. So, it is important to understand current status, past trends, and effectiveness of mitigation measures of air pollutant emissions in Asia. In order to provide fundamental information for these issues, we are developing Regional Emission inventory in ASia (REAS) and a long historical emission inventory during 1950-2015 were developed as REASv3.1. Clearly, emissions of all air pollutants in Asia increased significantly during these six decades, but trends of increase are different among countries and regions. For recent years, relative contribution from China was the largest along with rapid increase of economic growth, but most species reached their peaks until 2015 and growth rates of other species became at least small or almost stable. On the other hand, air pollutants emissions from India showed almost continuous increasing trends. As a result, relative ratios of emissions in India to Asia are increasing recently. Trends of Japan were different from those of total Asia. Emissions increased rapidly during 1950s-1970s reflecting economic situation during the period, but most emissions were reduced largely from peak values and years of the peaks were mostly before about 40 years due to introduction of regulations and lows for air pollution. Similar features were found in Republic of Korea and Taiwan. For other countries in Asia, emissions of air pollutants generally showed increasing trends along with economic growth and motorization.

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CALCULATION OF EMISSION FROM TRANSPORT IN MAJOR CITIES IN VIETNAM AND ESTIMATION OF EMISSION IN 2020

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In Vietnam, road traffic activities consist mainly of automobile and motorcycle, the motorcycle has increased significantly in recent years. The rapid increasing in the number of motor vehicles has the positive effects of economic, social, but if we don't controll the air emission, it will cause serious impact on the environment, polluting the air and greenhouse gas emissions, fossil fuel consumption, causing congestion, safety and disorderly especially traffic accidents. Emissions from vehicles containing toxic substances such as CO, HC, NOx, PM ... pollute the environment and affect human health, particularly in urban areas. To calculate the total emissions, we have to determine emission factors for each type of vehicle models in specific conditions (eg urban roads or rural roads, climatic conditions and other environmental factors), emission control technologies (eg incontinence, or use the catalytic converter etc ..), vehicles used, fuel used and especially the average mileage of a stable operating conditions for each specific vehicle. The calculation emission of air pollutants from traffic activities dependent on the accuracy of emission factors used and the method applied to calculate emissions. This study was conducted to develop method for calculating emissions from transport in line with the conditions of the big cities of Vietnam serving calculation of air pollutants from traffic in Vietnam to meet current urgent needs.

The results of air emission are presented for each vehicle category and each EURO standards of emission. The calculation results show that: (i) The air emissions for road transportation activities are for whole Vietnam for the year of 2014 and 2015; (ii) The results show that emissions of 2015 for NOx, CO, HC, CH_4, PM are higher than emission of 2014 about 9.33%, 11.25%, 10.45%, 9.22%, 9.45%, respectively; And (iii) If new policy is applied, emission reduction for the period of 4 years 2016 – 2019 for NOx, CO, HC, CH_4, PM will be 6.42%; 25.34%; 26.35%; 22.26% and 22.02% respectively.

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Improving monthly NH_3 emissions in China based on inverse model and observed data

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The increase of gaseous ammonia (NH_3) concentration in the atmosphere significantly impacts the regional air quality, human health and the nitrogen cycle of ecosystems. NH_3 emission inventories are an essential input in chemical transport models and are helpful for policy-makers to refine mitigation strategies. However, current estimates of NH_3 emissions in China still have large uncertainties. In this study, an improved estimation of NH_3 emissions during 2013 to 2016 in China has been made using the satellite data and surface observed data of Nationwide Nitrogen Deposition Monitoring Network (NNDMN). Some researches and the analysis of observation suggest that the increasing atmospheric NH_3 concentration during this period mainly due to substantial reduction of SO_2 and NOx emissions. So, the first step of this study is to validate and improve SO_2 and NOx emissions. Then the spatial patterns and monthly profiles of NH_3 emissions will be optimizing based on assimilating the long-term satellite NH_3 column. The amounts of NH_3 emission are updated by assimilating the surface NH_3 observations from NNDMN. The inversion results will be validated by several independent datasets such as EANET and published data, which contains gaseous NH_3 and ammonium deposition.

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Major outcomes from the EANET deposition monitoring

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Acid Deposition Monitoring Network in East Asia (EANET) started its preparatory phase activities in 1998 and regular phase activities was started in 2001. Referring the activities of the monitoring networks in Europe and North America or the world scale monitoring network like WMO/GAW, the monitoring methodology for wet and dry deposition has been developed and updated, especially focusing on the quality assurance and quality control on the monitoring. As of 2019, EANET has 62 and 54 sites for wet and dry deposition monitoring, respectively, in urban, rural and remote areas in thirteen participating countries. These monitoring data are released with various temporal resolutions and are widely used to study the atmospheric environment in this region. In the presentation, long-term trend of wet deposition such as acidic and basic substances as well as the ratio of sulfur and nitrogen species will be introduced taking into account the influences of long range transportation of air pollutants in northeastern part of EANET region. Besides, urban air pollution in the southeastern part of EANET region and landlocked county will be introduced by air concentration monitoring results which are monitored for calculating dry deposition amount of air pollutants. Because sulfur emission amount from the anthropogenic activities has decreased and precipitation was mainly acidified by sulfuric acid in the northeastern part of EANET region, acid deposition amount has decreased in the source region. Long-range transportation of acidic substances from the source area to the leeward area in the peninsula or islands has also decreased, even though the deposition amount there is still higher than that in North America and European countries. As for the case in Japan, such long-range transportation of sulfur species from the continent to Japan has also been confirmed by stable isotope analysis for rainwater. And of course, EANET data has helped to clarify the transport of air pollutants and might have contributed to the reduction of deposition. On the other hands, urban air pollution in southeast Asian country and landlocked county has been seriously due to high concentration of air pollutants and its human health effects. Therefore, our network is also expected to contribute to the clarification and countermeasure of such air pollutions in these areas.

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EANET ecological monitoring in a changing atmospheric environment in Asia

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In the Acid Deposition Monitoring Network in East Asia (EANET), in addition to the monitoring on atmospheric deposition in 62 sites, monitoring on ecosystem components in forest area has been carried out in 31 forest plots, 19 lakes/rivers, and 2 forest catchments within the same network. Since the regular EANET monitoring started in 2001, the observational data have been accumulated for more than 15 years in many of sites. According to the Third Periodic Report of State of Acid Deposition in East Asia (PRSAD3) published by EANET in 2016, no clear trend was found in soil chemical properties and forest growth rates in most of the sites, while a few sites showed reduction of acid neutralizing capacity in soil. Moreover, some sites for inland water showed acidification trends with increase of SO_4^{2-} and NO_3^- concentrations. However, the updated data suggested recovery of inland water from acidification, which might reflect reduction of atmospheric deposition. The long-term data since the 1980s also showed that biogeochemical processes in a forest catchment in Japan sensitively responded to changing atmospheric deposition and extreme weather (Sase et al. 2019, Biogeochemistry). Application of isotopic analysis to the existing monitoring samples showed new views on possible mechanisms. The presentation will be extended and updated from the version for IUFRO World Congress 2019.

Acknowledgements: The authors thank all the surveyors on EANET and Japanese national monitoring, the current/previous ACAP colleagues for their data compilation, and the scientists contributed to the isotopic analysis.

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European history on regional impact assessment

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This year the Convention on Long-Range Transboundary Air Pollution (CLRTAP) celebrates its 40th anniversary. Throughout its history, the Convention has supported policy makers with science-based approaches to effectively achieve air quality objectives. The exceptional structure, which consists largely of scientific programmes, has succeeded in achieving the reduction targets, particularly for Sulphur emissions. As part of the identification of highly sensitive ecosystems, the effect-based Critical Load approach was developed for the eutrophication and acidification effects of Sulphur and Nitrogen depositions. This approach incorporates findings from soil chemistry, the ecological field and the nature conservation community. The Coordination Center for Effects (CCE) of the International Cooperation Programme Modelling and Mapping (ICP M&M) was recently transferred from the RIVM in the Netherlands to the German Federal Environment Agency (UBA). The CCE is responsible for the continuous improvement of the scientific basis of the Critical Load approach and is also responsible for the creation and publication of a Europe-wide data set for Critical Load in cooperation with the national partners (NFC). This data set is continuously updated and is also embedded into the integrated modelling (The GAINS model at IIASA). It is also used to compare it with deposition data (EMEP/MSC-WEST) to calculate the exceedance of the Critical Load. This indicator is needed to quantify the success of emission reductions and to identify the intensity of further need for action. Time series of critical load exceedances are also an impressive tool to communicate reduction successes to policy makers.

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ICP Forests: Long-term, large-scale and policy-relevant forest monitoring in Europe

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Considerable concern was created by reports of poor tree crown condition (mainly defoliation and discoloration) from parts of central Europe during the late 1970s and early 1980s. At that time emissions of pollutants from transport, agriculture, energy production, industry and households were high in Europe, and air pollution and acidic deposition were often reported (but seldom proofed) to be a predisposing factor in the so-called “Waldsterben” (forest death) syndrome in Europe. Against this background, the International Cooperative Program on Assessment and Monitoring of Air Pollution Effects on Forests, ICP Forests, was launched in 1985 as part of the UN Economic Commission for Europe's (UNECE) Convention on Long-range Transboundary Air Pollution (now termed Air Convention). The Convention (originated in 1979) provides a general framework for collaboration to limit, gradually reduce and prevent air pollution. Initially aimed at reducing the effects of acid rain through control of sulphur emissions, its scope was later widened to include nitrogen pollutants, volatile organic compounds (VOCs), heavy metals, and persistent organic pollutants (POPs). Forty-two countries participate in ICP Forests. ICP Forests monitors forest conditions based on harmonized methodologies in Europe at two monitoring intensity levels: (i) the Level I monitoring, which is based on ca. 6000 observation plots on a systematic transnational grid of 16 x 16 km across Europe and beyond, aims at assessing the geographic and temporal variations in forest condition. (ii) The Level II, intensive monitoring comprises around 800 plots in selected forest ecosystems with the aim to clarify relationships between possible drivers (e.g. air pollution, climate) and forest response (e.g., tree condition and growth, species diversity, soil and foliar nutrition). In this presentation, an overview about the bodies and structure of program, the history of ICP Forests, how it develops harmonized methodologies at pan-European level, its main results, and how the monitoring of the status of European forests contributed knowledge for the assessment of the effectiveness of policies in protecting the environment. The Air Convention in general, and ICP Forests in particular, is exemplary to show how joint action can succeed in achieving important environmental targets.

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Concentration and pattern of Ozone (O_3), Sulphur dioxide (SO_2), Epicuticular wax & Elemental carbon between 2015-2017 in Bintulu, Sarawak, Malaysia

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The economic development and intensified human activities contribute to the poor air quality and occurrence of urban heat island. The objectives of study were to assess the O_3, SO_2 epicuticular wax and elemental carbon concentrations and effects on urban tree. Ogawa passive samplers were installed to measure O_3 and SO_2 concentrations and filters were collected monthly over two years and measured using Ion Chromatography. Standard methods were used to measure elemental carbon and epicuticular wax concentrations. Data analysis suggested O_3 and SO_2 average over two years were within safe limit (<0.10 ppm) and (<0.13 ppm). O_3 related injury was not observed but sign of biotic diseases were prominent. Epicuticular wax concentrations were higher in industrial areas whereas elemental carbon concentrations were similar across all study sites. Long term monitoring is still required to understand these concentrations and patterns.

Keyword: Ozone (O_3), pollution, Sulphur dioxide (SO_2), epicuticular wax, elemental carbon, Bintulu

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Carbon storage potential in Bintulu's forest rehabilitation project

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Forest ecosystem is an important reservoir for carbon but the carbon stock has decreased due to forest conversion and degradation. This elevates the role of the remaining natural regenerating secondary and rehabilitated forests in (i) biodiversity conservation, and (ii) providing goods and services to mankind. The objective of this study was to estimate the carbon potential storage in a rehabilitated forest. This study was conducted at UPM-Mitsubishi Corporation Forest Rehabilitation Project. 20 x 20 m study plots were established at 19-year-old (Plot 1991), 10-year-old (Plot 1999) and 1-year-old (Plot 2008). Biomass was estimated using a modified allometric biomass equation while half of biomass is carbon. From the analysis, the estimated forest biomass after 28 years is 173.6 t/ha or carbon storage potential of 86.8 tC/ha.

Keywords: rehabilitated forest, carbon, biomass, Bintulu

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The Acid Deposition Monitoring Activities in Cambodia

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Acid rain is a term that refers to any form of precipitation with acidic components that fall to the ground in wet or dry forms. Many scientific papers have linked acid rain to the increase of environmental degradation, a contributing factor in the decrease of fish and wildlife population, and the contamination of water sources. Since 2001 Cambodia is strongly committed to implementing EANET activities, including regularly monitoring of wet and dry deposition in Phnom Penh and Siem Reap province as well as inland aquatic at Sras Srang Lake, Preah Suramarit-Kossamak Kirirom National Park in Kompong Speu Province. In addition, Cambodia also started to monitor PM2.5 in Phnom Penh since April 2017 and has recently received an ozone monitor system from ACAP in August 2019. The Ministry of Environment of Cambodia has also been at the forefront of the participation with international community in order to collect data, monitor, and make sound decisions to reduce the adverse impacts on the environment. Furthermore, the Ministry also disseminates public awareness of the importance of environmental protection and share basic knowledge about the acid deposition monitoring program to university students through our internship program.

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Polycyclic aromatic hydrocarbons (PAHs) associated with PM10 among Ger districts in Ulaanbaatar, Mongolia: concentration, distribution, and cancer risk assessment

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During the long cold season, air pollution level in Ulaanbaatar (UB) is among the highest in the world. As a result of rapid urbanization and population growth, air pollution of UB have got worsen dramatically in recent several decades. Intensive rural-to-urban migration resulted sharp increase of traditional Ger settlements are in UB. Approximately 60 percent of city's population of total 1.5 million people live in Ger (traditional circular dwelling) district and 180 thousand of traditional stoves are working and burning raw coal and wood during the winter season.

Household coal combustion has been identified as main source of air pollutants including particulate matters and toxic organic pollutants. Among the various toxic compounds, polycyclic aromatic hydrocarbons (PAHs) have taken great attention and widely studied globally due to their carcinogenic and mutagenic properties. In this study, PAHs associated with PM 10 (particulate matter with aerodynamic diameter less than 10 μm) in ambient air of Ger districts were investigated in order to determine concentration level of PAHs and to evaluate its cancer risk. Approximately one hundred PM10 samples were collected from four different sites in Ger districts during February to April in 2019. Samples were extracted and analyzed with Gas Chromatography with Mass Spectrometer detector (GC-MS). Results showed that average concentration of total PAHs associated with PM10 is 199±115 ng/m^3 (49–439 ng/m^3) and is relatively higher than other measured values around the world, but similar with that in the most polluted cities in China. PAHs with 4–5 rings are dominant and PAHs ratios revealed that they mainly emitted from biomass combustion and petroleum. Carcinogenic PAHs is accounted for 46 percent of the total PAHs. Benz[a]pyrene cancer equivalent factor is estimated to be 32±17. In approximately 90 percent of analyzed samples, benz[a]pyrene concentration exceeded national permissible level of 1 ng/m3.

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Spatial and temporal variations of sediment metals in the Tuul River, Mongolia

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Mongolia has been a pristine environment without much pollution. Our objective is to study a section of the Tuul River to evaluate the present condition of this pristine environment. Sediment metal (Al, Fe, Mn, Cu, Zn, Pb, Ni, Cd, Hg, and Cr) concentrations and Pb-210 were sampled and analyzed. Results showed that metal concentrations are much higher at areas near the capital city and municipal sewage outlet, with enrichment factor values up to 18 for Cu, and 26 for Cr. Higher copper concentrations were found at sites about ~ 50 km downstream from the source, an indication that pollutions are spreading further down the river. Vertical metal concentration profiles indicated that pollutions could be traced back to the 1960s. Inefficient sewage treatment plants and poorly managed power plant ash ponds were major sources of metals leaking into the Tuul River. Sewage wastewater is carrying metals through Tuul River to the lower river basin. Dusts from ash ponds are airborne and transport to greater area. These findings indicate that new and alternative measures have to be enforced to prevent further pollution entering the Tuul River drainage basin and airborne dust to other broader regions of the Asia and ocean.

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Sources, pollution, and mobility of soil metals in Ulaanbaatar, Mongolia

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This study was conducted to evaluate the enrichment and potential mobility of metals in urban soils of Mongolia and to identify major sources of soil metal pollution. The concentrations and geochemical fractions of Al, Fe, Mn, Cr, Cu, Cd, Co, Zn, V, Mo, As, Sb, and Pb in soils of the city Ulaanbaatar were investigated. The results demonstrate that only Fe, Mn, Co, Mo and V occur at natural levels with enrichment factors close to unity. The majority of investigated toxic metals, including Cu, Zn, Cr, Sb, As, Cd, and Pb, are serious pollutants in urban soils, with enrichment factors of up to 2.8, 5.1, 2.1, 16, 14, 13, 15, and 11, respectively. Studies of the chemical fractions of metals demonstrate that Zn is mainly found in its labile form and is considered a high risk to humans and biota. Industrial waste, household ash, coal combustion, and tire abrasion, which may be exacerbated due to the nationwide unregulated use of aged tires, are major sources of toxic metals entering into soil of Ulaanbaatar city. Further improvement in regulation and monitoring of these sources is needed to prevent population exposure to toxic metals as well as pollution distribution over a wider area by atmospheric long-range transport.

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Development of the analytical method for sulfur isotope ratio of SO_2 gas and survey.

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We investigated behavior of S in forest area by isotopic analysis. According to the previous study, $\delta^{34}S$ of throughfall (TF) was a little higher than that of rainfall (RF). To consider this reason, dry deposition of S is important. S inputs by dry deposition process are derived from particulate SO_4^{2-} and gaseous SO_2. But so far, isotopic analysis has mainly been applied to water or particular samples. Moreover, the current ambient air SO_2 concentration in Japan is very low compared to that of particulate SO_4^{2-}. Therefore, in this study, we developed analytical method for S isotopic ratio of SO_2 gas.

An impregnated filter with K_2CO_3 that was commonly used for filter pack sampling to collect SO_2 and a high volume air sampler (HV) were applied for sampling. The filter was made by impregnating a cellulose filter (ADVANTEC 51A, 26 cm×20 cm) with 15% K_2CO_3 and 2% glycerin. This filter and quarts filter to collect particular matters were used. HV was used due to low concentration of SO_2 (< 0.2 ppb) in Japan. 2,000m^3 of air sample was needed to obtain enough sulfur oxides for S isotopic analysis. The K_2CO_3 filter was extracted by 0.05% H_2O_2 and filtered. The solution was concentrated under pH 4～6 to remove CO_3^{2-}. Then $BaCl_2$ was added and completely evaporated. The precipitation was washed and collected on a filter paper. The $BaSO_4$ precipitation was obtained after ashing. It was analyzed by IR-MS. Isotopic ratio ($\delta^{34}S$) was expressed as the difference from the standard, Canyon Diablo Troilite (CDT).

The $\delta^{34}S$ values of SO_2 were usually lower than those of particulate non-sea salt SO_4^{2-} (nss- SO_4^{2-}). The $\delta^{34}S$ value of particulate nss- SO_4^{2-} was higher in winter and lower in summer. But that of SO_2 didn't have clear seasonality. It was suggested that nss- SO_4^{2-} and SO_2 had different sources. Given that SO_2 is oxidized to SO_4^{2-} during transportation, the $\delta^{34}S$ value of SO_2 is affected by relatively nearer sources. Dry deposition of SO_2 isn't considered as a reason for the difference between $\delta^{34}S$ values of RF and TF.

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Temporal variation of atmospheric dry deposition at Kaba-aye site, Yangon in Myanmar

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Atmospheric dry deposition of gaseous (SO_2, NH_3, HNO_3, HCl) and particulate ions ($SO4^{2-}$, NO^{3-}, Cl^-, NH^{4+}, Na^+, K^+, Mg^{2+}, Ca^{2+}) during 2012-2017 were investigated at Kaba-aye site, Yangon, Myanmar. The investigation of this study aimed to understand the temporal variations and behavior of atmospheric dry deposition at the Kaba-aye site. The study results observed that, the mean concentration of pollutant gaseous in a descending order were NH_3 > SO_2 > HNO_3 >HCl. The concentration of cations in descending order were Ca^{2+} > $NH4^+$ > K^+ > Na^+ > Mg^{2+} and that of anions were $SO4^{2-}$ > NO_3^- > Cl^-. The dominant pollutants in the study area were observed as NH_3 and SO_4^{2-}. Temporal variation of gaseous and particulate ions species showed lowest concentration during wet season (June to October) and highest in dry season (November to May). All gaseous were decreasing trend in both dry and wet season except HNO_3, while both positive and negative trend in pollutant ions. This study found NH_3 had higher concentration than SO_2 that reflecting NH_3 emissions had a larger influence than SO_2 emissions during the study period.

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Bamboo, grass who protects the Global Warming

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Worsening air pollution as result of economics expansion is leading to higher acidity in rainwater in cities across Asia, according to study. In Thailand, the Pollution Control Department's monitoring showed that the big cities as Bangkok and Chiang Mai was the highest chemical deposition. However, the acid rain was not yet at a dangerous level. The more worrying situation is the Global Warming. The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming highlights climate impacts at the current ~1°C global warming as well as the risks of reaching a 1.5°C and the irreversible losses that would take place at 2°C or more warming. Forests are vitally important as they soak up carbon dioxide, the main greenhouse gas responsible for global warming, and help regulate the world's climate.

Bamboos are giant grasses, meaning that their extensive root and rhizome systems can bind soil and allow for annual regrowth after harvesting, while it is one of the fastest growing plants in the world. This makes it particularly suitable as a tool for carbon sequestration. Its capacity to absorb carbon emission from the atmosphere makes it a viable material of choice to reduce global warming. It grows faster than wood and under favorable conditions can have healthier, stronger and flexible culm. In addition, bamboo can be effectively used to rapidly restore degraded lands, provide a sustainable energy source for households and generate income for millions of people.

Thailand has around 15-17 genera of Bamboo such as Dendrocalamus, Gigantochloa, Bambusa and Thyrsostachys and 80-100 species such as *Dendrocalamus asper*, *Gigantochloa albociliata*, *Bambusa bambos* and *Thyrsostachys siamensis*. From the data collection, 3-year-old bamboo in Thailand with the intensive management could absorb carbon dioxide was about 99.98 ton/ha. Comparison to the carbon dioxide absorption in the fast growing tree species in the same age as *Eucalyptus camaldulensis* and Acacia hybrid were 80.74 ton/ha and 79.60 ton/ha, respectively, while Thai native tree species as 3-year-old *Tectona grandis* carbon dioxide absorption was only 4.52 ton/ha. Moreover, the characteristics of bamboo such as fastest growing plant in the World (up to 91 cm/day), grows back quickly after being harvested and does not require replanting after harvesting, takes only 5 years to be harvested, including it can store carbon in a large number of durable products, as well as in the plant itself. Over time, this means that bamboo can sequester more carbon than some tree plantations. Bamboo is one of the important species for decreasing the climate change.

Keywords : Bamboo, carbon dioxide absorption, global warming, climate change

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Estimation of sulfur and nitrogen budget on the small river catchment at Russian EANET Primorskaya station

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Ecosystems at the Russia Far East are supposedly affected by continuous influence by not only by local air pollution but also by transboundary air pollution. In order to assess the impact of air pollution on ecosystems, we carried out the primary task of calculating the input-output budget of sulfur and nitrogen compounds for a specific catchment area of Komarovka River. The study catchment area is about 155 m^2 covered by a deciduous forest. The catchment is situated far from the main emission sources with almost no visible influence of anthropogenic activity, which makes it applicable for transboundary pollution studies. Data for the flux estimation were taken from long-term monitoring at the EANET Primorskaya station, which has been operating there since 2002. Firstly, we separately calculated the chemical compound fluxes for wet deposition, dry deposition, and river runoff. The trend analysis was also performed for annual concentrations and their fluxes. Declining trends were identified for the dry deposition of sulfur and nitrogen compounds, although significant declining trends for annual concentrations in air were detected only for sulfur compounds. The annual fluxes by wet deposition in most cases exceeded those by dry deposition, except for some years. Due to the small number of surface water sampling during the year, use of the usual interval-representative method can induce uncertainties for the total flux calculations. The chemical compound budgets were calculated according to a simplified model where the input consists of wet and dry deposition, and output is represented solely by the discharge with the river flow. For most years, the output of nitrogen compounds was lower than the input. On the contrary, the output of sulfur compounds exceeded their input. The similar cases were shown in some works for Europe and America.

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30 years of deposition monitoring in European forests – are sulphur and nitrogen still an issue?

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A pan-European throughfall (TF) deposition monitoring network (Level II plots) for sulphur (S), inorganic nitrogen (N) and base cations was established in the decade following the launch of ICP Forests in 1985. The use of harmonized methods for sampling and quality control procedures for laboratory analysis yielded a unique long-term dataset suitable for comparison between countries. The data series are an excellent basis to assess the status, trends and spatial patterns in deposition, allowing to evaluate the success or failure of clean air policy. For example, acidifying deposition in Europe sharply decreased following an overall successful reduction of sulfur dioxide (SO_2) emissions. On the contrary, the reduction of N emissions started later and was more limited with large spatial differences related to socio-economic development. Accordingly, N deposition still exceeds the critical loads for oligotrophic bryophytes, lichens and higher plants at many plots and particularly in Central NW-Europe. In addition to (1) visualizing these effects of emission reduction measures, the ICP Forests deposition monitoring has also contributed to (2) an understanding of the effects of deposition on forests (e.g. tree health, biodiversity, ground water quality), (3) scenario-based assessments of future policy options and (4) improvements of large-scale air pollution modeling by providing reference data. Continued monitoring is needed to follow up the effects of changes in policy and fulfill reporting obligations (e.g. EU National Emission Ceiling Directive) besides efforts to consolidate existing monitoring data among the institutions involved across Europe.

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Impacts of air pollutants on soil and soil solution chemistry as revealed by the UNECE ICP Forests monitoring programme

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Forest soils in Europe have been highly impacted by air pollution. As many forest soils in - especially the northern and western part of - Europe are poor in bases and limited in nutrients, acidification and nutrient imbalances by eutrophication are widespread phenomena. In addition, pollution with toxic heavy metals is also of concern for soil functions in large forested areas in Europe. Finally, the risk of losses of soil organic carbon (SOC) due to climate change may also alter soil processes and functions in forest ecosystems. Monitoring of air pollution effects on forest soil functions within the UNECE ICP Forests monitoring programme is conducted at two levels of intensity. So far, two soil chemical inventories were accomplished (1985-96 and 2004-2009) at a regular 16x16 km grid across all forested sites (Level I, > 5000 plots). The second soil inventory was combined with assessments of crown condition, stand structure and plant biodiversity. At more than 500 Level II plots, more intensive observations are conducted partly including regular soil solution sampling. Large reductions of deposition of acidity (mainly sulphates) across most parts of Europe induced the recovery of many forest soils from acidification as indicated by an increase of base saturation or an increase of the base cation to aluminium ratio in soil solution. At some areas de-acidification was supported by forest liming. However, large areas of forested soils are still critically acidified. Where critical loads of acidity are still exceeded, forest soils even tend to acidify further. Large forested areas in Europe are nitrogen saturated due to atmospheric nitrogen deposition. Repeated soil inventories and nitrogen budgets from Level II plots suggest that nitrogen is accumulated in most of these forest soils. With respect to SOC stocks, both gains as well as losses are observed in forest soils across Europe. A major challenge is to identify management practices, which support the preservation of SOC and nutrient budgets for a sustainable forestry under a changing climate.

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Large-scale assessments of ozone effects on symptom development and forest growth

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Tropospheric ozone has large impacts on plant metabolism and functions at individual tree level. However, due to the presence of several compensatory and acclimation mechanisms, and to interactions between ozone and other environmental stressors, its long-term impacts on forest functions and dynamics at larger spatial scales is controversial (see Cailleret *et al*. 2018).
Ozone concentrations, ozone-induced visible foliar symptoms and forest growth have been assessed according to ICP Forests standardized methods. A linear-mixed-effects modeling approach was applied to analyze temporal trends in ozone concentrations and symptoms and their intercorrelation while accounting for heterogeneity and completeness of the datasets. Trend analysis reveals a slight but significant decrease in growing season (April–September) ozone concentrations (Schaub *et al*. 2018). There were no clear spatial or temporal trends in mean ozone symptoms, but we found differences among biogeographical regions.
For quantifying ozone impacts on forest growth, we combined the above indicated ICP Forests data with modeled data from EMEP. We considered mean ozone concentration, AOT40 and POD1, and applied multiple statistical and re-sampling techniques to account for confounding abiotic and biotic environmental factors. We found large uncertainty in the estimation of ozone metrics with a strong variability across sites. The estimated relationships between ozone and tree- or stand-scale growth strongly depend on the sample characteristics (spatial and temporal coverage) and on the data source used (modeled *vs*. measured). Our study provides new methodological insights on the data required to improve large-scale assessments of ozone impacts on forest ecosystems.

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Monitoring of tree condition as a part of UNECE ICP Forests: pressures, damage and trends

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The crown condition assessment was the first monitoring activity within ICP Forests and is still carried out annually on more than 100 000 trees/6000 Level I plots and around 500 Level II plots in Europe. Since ICP Forests uses the knowledge of national monitoring activities established prior to 1985, the crown condition Manual reflects the differences stemming from national experiences, and a lot of effort has been put into the harmonization and intercalibration of methods, and, where this was not possible, into the intercomparison of results obtained by different methods. Crown assessments were started in order to determine, assess, and monitor the effects of air pollution on forests, as in the 1980s air pollution was supposed to significantly affect crown condition. The experience gained through long-term forest monitoring has shown that a wide array of environmental and anthropogenic pressures, including climate change, influence the vitality of forest trees. Weather conditions are major drivers for year-to-year variations in crown condition, either directly, or by making forest trees more vulnerable to damage from fungal diseases or insects. The crown condition survey nowadays consists of a defoliation assessment complemented by a damage cause assessment. Defoliation is an indicator of tree vitality, significantly linked to fine root mortality, reduced radial growth, and tree mortality. The trend of defoliation in the past 20 years has been significantly increasing for Norway spruce, Scots pine, Austrian pine, and Mediterranean lowland pines, common beech and evergreen oaks. Insects, abiotic causes and fungi are the most common damage agent groups, comprising together more than half of all damage records. The main cause of death to both conifer and broadleaved trees are abiotic factors. The quantification of forest ecosystem behaviour in a changing environment remains fundamental for forest management and the maintenance of forest ecosystem services.

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Long-term growth monitoring in European forests

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In 1991, now nearly 30 years ago, in the light of increasing forest decline, it was acknowledged that the growth of trees is a key ecological parameter of forests condition and one of the indicators of forest health. This resulted in an establishment of Level II intensive monitoring of the forest ecosystems where growth was one of the central parameters.

Measured (DBH, height) and calculated (BAI, volume, radial increment) growth parameters can be linked to external as well as internal factors serving as a proxy for the response of trees and stands to changes in site and environmental conditions. The assessments on the Level II are carried out every 5 years and are mandatory. To fill the data gap between two, subsequent surveys, manual girth bands are installed on the trees to provide information on the yearly increment (which is later on combined with the data of 5-year surveys). In addition to these measurements, past growth can be reconstructed using methods of dendrochronology and may be used as a proxy for past environmental conditions. Collected parameters of stand structure also provide information for the interpretation of other assessments carried out, such as development of ground vegetation, crown defoliation, throughfall, and others.

Currently there are more than 400 Level II plots installed in Europe. Data at the plots are collected in a harmonized way to ensure comparability of the results and are stored in a central ICP Forest database. Data in the database are constantly checked for quality and errors and evaluated after every survey. Growth data from Level II plots are also available for the external use. So far, they have been used for different studies of growth response to environmental conditions (including climate change), estimation of the aboveground carbon sinks and / or mortality trends in European forest.

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Transition of atmospheric N deposition in China and its implications

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China has experienced a dramatic increase in atmospheric reactive nitrogen (N) emissions due to intensified human activities over the past three to four decades. As a result, China especially eastern China has been a "hotspot" of atmospheric N deposition worldwide. In order to quantify atmospheric N deposition fluxes and trends in China, we systematically evaluated N bulk/wet and dry deposition based on Nationwide Nitrogen Deposition Monitoring Network (NNDMN), other monitoring networks and published data from literature. As a whole, atmospheric N deposition has experienced three stages: increasing, stabilizing and decreasing stages in China. We found N deposition reached its historical peak around 2000 then it entered a relatively short stabilized stage then steady declining stages, along with the trade-offs between dry versus wet deposition and/or oxidized versus reduced N deposition. Both the deposition database and observational results show that bulk/wet deposition has decreased since 2000. The average total dry and wet/bulk deposition during 2015-2018 (37.5 kg N ha^{-1}) was lower than that during 2011-2014 (42.2 kg N ha^{-1}). The oxidized N deposition, especially in dry deposition, decreased remarkably from 2010, which was attributed to NOx emission control measures taken by Chinese government. However, the reduced N deposition leveled off from 2011 to 2018, and the mitigation of NH_4^+-N deposition via wet/bulk (precipitation) was offset partly by a continuous increase NH_3 dry deposition. Particularly, the high NH_3 concentration at urban monitoring sites implied the influence of non-agricultural sources. Initial evaluation suggests that atmospheric N deposition has been an important nutrient input to water bodies (lakes, rivers and coastal seas) and its contribution to eutrophication can never be neglected in China. For example, annual total N deposition to the Yangtze River Basin was up to 33.2 kg N ha^{-1} or 6.0 Tg N, comparable to N leached or runoff from arable soils. Atmospheric N deposition (75 kg N ha^{-1} yr^{-1}) is also proved to be significant nutrient input to Dongting Lake in the middle reaches of Yangtze River. Our analyses of the decadal changes in the local and national atmospheric N deposition across China could be used as a reference for mitigating China's nationwide air and water pollution as well as sensitive ecosystem (including forests) recovery in the future.

Key words: Atmospheric deposition, Reactive N, Ammonia, Air Pollution, Emission control.

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Regional impact assessment on acidification/N saturation in the East Asia: a critical loads approach

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Spatial variations in S and N deposition have changed during past several decades in East and Southeast Asia. To assess the future eutrophication (N saturation) and acidification risks, a risk map by critical loads approach should be updated and improved by considering bedrock, soil type, climate and land-use change in this area where these environmental factors are largely different from Europe and North America. Input data for critical loads (base cations (BC) deposition, weathering rate, removal and discharge of N and BC from the ecosystems) was estimated from the geospatial information of soil, geology, climate, vegetation and the monitoring data by EANET. To assess the spatial-temporal change of critical loads exceedance, annual S and N depositions were simulated by CMAQ atmospheric chemical transport model with 80km (1981 - 2005) and 45km (2013) grids. As a result, the range of S and N deposition in 2000-2013 did not exceeded critical loads of acidification in east and Southeast Asia whereas N deposition exceeded critical loads of eutrophication in tropical monsoon area and south and northeast China. This suggested that eutrophication risk was much higher than acidification risk in the area. Particularly, the discharges of BC and N from the ecosystems may play important role for the spatial variation in critical load of eutrophication in the area. The discharge rate was strongly regulated by not only precipitation but also plant uptake which was estimated from the vegetation and land-use type. This also suggested that the critical loads in this area may include a large uncertainty due to the land-use change and an increase/decrease of forest NPP which might be derived from climate change. We also verified the eutrophication and acidification risk in this study by existing observations and reports.

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Estimation of atmospheric deposition load and its effects on nutrient dynamics in forest ecosystems using Sr and Pb isotopes in soil

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Detection of forest declination sign is of great interest because load of transboundary air pollutants into forested ecosystems is continuing high level in Japan. In this study, isotope analysis of heavy metals (mainly, strontium (Sr) and lead (Pb)) in forest soils collected from more than 40 sites in Japan was conducted taking advantage of the features of heavy metals, 1) heavy metals entering into ecosystems via atmospheric deposition are stored in soil organic matter and/or soil minerals, 2) provenance of air pollutants can be estimated by their isotope ratio, 3) geographical distribution pattern of multi isotopes will enable us to estimate amounts and date of atmospheric deposition load. Correlation analysis between Sr isotope ratio and other soil properties (e.g., soil nitrogen (N) transformation rates and chemical components of soil) which are sensitive to environmental change showed that Sr isotope ratio could be used as an index of soil acidity, and so far no significant effect of soil acidity on soil biological properties (soil N transformation rate). Estimation of Pb fractionation in soil, which was necessary before ecosystem effect assessment, showed that Pb was distributed most in organic fraction of soil (EDTA extracted fraction). Further analysis will continue to reveal the relationship among air pollutants load, soil properties, and forest growth.

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Ozone impacts on Japanese forest tree species

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Effects of ozone on Japanese forest tree species have been studied since 1970s. Based on the results from ozone fumigation studies, current ambient levels of ozone may induce negative impacts on growth and physiological functions of Japanese forest tree species. Theses experimental studies also indicate a big variation of ozone sensitivity between tree species, and the sensitivity is modified by the other environmental factors such as elevated CO_2, soil nutrient condition and water stress. Stomatal ozone uptake is considered as one of the key factors for evaluating ozone sensitivity and risk assessment. Although ozone generally induces stomatal closure, less efficient stomatal control (so-called stomatal sluggishness) is also induced by chronic exposure to ozone. These opposite phenomena result in complex responses of stomata to ozone. The detail gas exchange analysis revealed that ozone-induced reduction in photosynthetic rate of Japanese forest tree species was mainly due to biochemical limitation in chloroplast but not due to stomatal closure. And the reduction of nitrogen allocation to photosynthetic apparatus contribute to the greater biochemical limitation under elevated ozone. Risk assessments of ozone impact on Japanese forests tree species based on the results of experimental study, national monitoring data of air pollutant concentrations and vegetation survey indicate that the areas with high ozone -induced reduction in growth did not necessarily correspond to the areas with high ozone-exposure. To develop the understanding ozone impacts on Japanese forest tree species, free-air ozone fumigation systems were carried out in northern Japan from 2011-1014. The studies with this novel technology have clarified the difference of leaf ozone sensitivities between canopy positions, and have estimated the effects of ozone on whole-canopy carbon budget. In the presentation, future perspectives for developing the evaluation of ozone impacts on forest ecosystems will be discussed.

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Effects of ozone pollution on Chinese woody plants: an overview

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This presentation reviewed effects of elevated ozone on tree species in China based on the results in last two decades. The high ozone concentration in summer in most parts of China has induced the typical ozone symptoms in urban and mountain forest tree species. By using open-top chambers, elevated ozone affects the growth, gas-exchange rate, foliar microscopy, antioxidant system, BVOC emissions. The effects of ozone on biomass accumulation depend on the ozone concentration, tree species sensitivity and exposure duration. Different sensitivity to ozone among woody species are much related with leaf mass per area (LMA) but not with stomatal conductance or antioxidant capacity. The ozone uptake of individual tree species was also investigated by sap flower technique. Further studies has been conducted on the interactions between O_3 and other environmental factors such as increasing CO_2 concentrations, increased nitrogen deposition and drought. Ozone-FACE facility was developed at poplar plantation. Future needs for research include the below-ground ecosystem to elevated ozone, development of a general ozone flux model for most widely used tree species and assessment of ozone removal by urban forestry in a regional and national scales.

Keywords: biomass, elevated CO_2, forest tree species, gas exchange, N deposition, ozone