IUFRO RG 7.01.00 "Impacts of Air Pollution and Climate Change on Forest Ecosystems"

2013 Annual Report

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1. The RG 7.01 biennial conference in Ilheus, Brazil, September 2013

Conference "*Vegetation Response to Climate Change and Air Pollution - Unifying Research and Evidence from Northern and Southern Hemisphere"* was the main scientific event of the RG 7.01.00 in 2013. The meeting was held in Tororomba Hotel, Ilhéus, Bahia, Brazil, on September 1-6, 2013. WP 7.01.02 and specifically its officers, Alessandra Kozovits, Rainer Matyssek and Gerhard Wieser, as well as other RG 7.01.00 officers prepared scientific program of the conference and organized and chaired individual sessions. Alessandra Kozovits and her team of the Federal University of Ouro Preto, Brazil hosted the meeting. There were 85 participants in the meeting from 23 countries (Australia, Austria, Brazil, Canada, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Indonesia, Italy, Japan, Lithuania, Portugal, Romania, South Africa, Spain, Sweden, Switzerland, Turkey, USA) who presented 42 talks and 34 posters.The conference was sponsored by the Post-Graduate Program in Ecology of Tropical Biomes, Federal University of Ouro Preto, Brazil; the Gorceix Foundation, Brazil; the Brazilian Council for Scientific and Technological Development (Ministry of Science and Technology); as well as the Coordination Center for the Improvement of Higher Education Personnel, Brazil (Ministry of Education).

Figure 1. IUFRO Research Group 7.01.00 group picture at the cocoa plantation (photo credit - Andrzej Bytnerowicz).

Pre-conference scientific tours were organized to mangroves, Atlantic forests and cocoa plantations of the Bahia state. Mangroves of the Camamu Bay, exemplified importance of these ecosystems as repositories of marine biodiversity, provision of natural resources and ecosystem services (e.g., stabilization of shorelines and reduction of impacts of natural disasters such as tsunamis and hurricanes). Atlantic forests, which stretch along the coast of Brazil, are one of the global hotspots of biodiversity; however, they face tremendous pressure from the increasing population pressure and various forms of anthropogenic stresses. Current research efforts focus on better understanding of their functioning needed for effective protection and conservation.

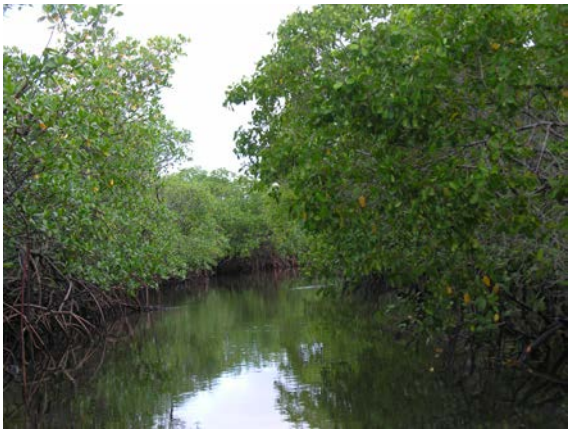

Figure 2. Mangrove forest of the Camamu Bay, Bahia (photo credit - Andrzej Bytnerowicz).

In Bahia, Atlantic forests contain extensive cocoa plantations with high importance for economic well-being of the Region. The "witches broom disease", caused by fungus *Crinipellis perniciosa,* devastated cocoa plantations in the late 1980s and 1990s causing high unemployment and multiple socio-economic problems. Local researchers from the Executive Plan for Cocoa Farming (CEPLAC) have developed 12 genotype varieties of cacao tolerant to "the witches broom disease" allowing for a recovery of the cocoa production in Bahia.

Figure 3. Atlantic forest with cocoa trees in understory (photo credit – Rainer Matyssek).

Figure 4. Cocoa tree (Theobroma cacao) – (photo credit - Rainer Matyssek).

Figure 5. Drying of cocoa seeds in the open-air conditions (photo credit – Rainer Matyssek).

1.1. Synthesis of Scientific Presentations

The main goal of the conference was to stimulate trans-hemispheric research collaboration with emphasis on ecosystems of the Southern hemisphere. For the first time the 7.01.00 scientific community met in South America, with particular consideration of research demands in Brazil. Research networking aims at joint research projects on identification of risks to health, biodiversity and sustainability of natural and cultivated forests in South America and other parts of the world. Such projects are aimed at mitigation of anthropogenic stress impacts with a focus on forests and other woody-plant ecosystems in Brazil (e.g. on Amazonian and Atlantic rain forests and Cerrado vegetation). This is of high importance because such vegetation types determine global carbon storage and the associated buffering of atmospheric CO_2 enrichment with risks of climate warming and exacerbated drought.

Such forest and woodland functions are threatened by land-use changes, typically driven by forest burning, which in turn releases precursors of air pollution. In Brazil, about 75 % of such precursors originate from land-use change rather than emissions from transportation and industrial sectors, and are responsible for elevated ozone concentrations in the troposphere. Ozone at enhanced regimes is regarded worldwide as potentially most phytotoxic air pollutant restricting capacity of forests to store carbon. This phenomenon is exacerbated on both hemispheres by regionally enhanced nitrogen and heavy metal deposition caused by

agricultural practices (in addition to combustion of fossil fuels) and open-pit mining (e.g. in the State of Minas Gerais, Brazil). There is a research gap in understanding air pollution effects, as part of climate change, on natural and managed forest and woodland ecosystems. This issue is of high scientific priority because of ample biological diversity of these ecosystems still present in South America and other parts of the Southern hemisphere.

The opening general session, chaired by **Alessandra Kozovits** (Brazil; WP. 7.01.02), consisted of four keynote presentations outlining most important topics for the meeting scientific context. **Mercedes M. C. Bustamante** (Brazil) presented a talk "*Challenges for the conservation and sustainable use of forests in South America*". She emphasized the prominent diversity of climate zones and habitats in South America that requires research optimization in view of the unprecedented interactions between local and global environmental changes. In creating an interface to the socio-economic approach, proper incentives need to be identified in controlling land-use changes. These should be supported by trans-continental research networks and strategies for optimizing integration of fragmented political institutions and decision-making processes**. Fabio R. Scarano** (Brazil) elucidated capacities in "*Ecosystem-based adaptation (EbA) to climate change*" in the specific case of Latin America. EbA represents a concept anchored in multi-scale land-use practices on the premise that sustained ecosystem services reduce the vulnerability of society to climate change. EbA currently spreads across the sub-continent, although consolidation will require trans-continental political collaboration. **Marisa Domingos** (Brazil) in her talk "*Monitoring the effects of air pollutants on remnants of native vegetation in SE Brazil"*, presented a regional focus on diverse anthropogenic pressures and land-uses on the Atlantic and semi-deciduous forest. Bioindication based on morphological, biochemical and physiological tree responses helps in identifying such effects. However, capacity for bioindication is limited because of multi-factorial impact scenarios, species richness and vague knowledge on cause-effect relationships. The southern-hemispheric dimension was outlined by **Thomas Seifert** (South Africa) who reported on "*Climatic influence on resource partitioning and competition between trees*" under the perspective of the arid sub-Saharan Africa which is becoming a hotspot of drought. Response patterns of woody-plant ecosystems to climate change scenarios remain uncertain as being super-imposed by episodic events such as fires, although evidence suggests gradually altered competitive plant-plant interactions in savannas, exotic plantation forests and indigenous high forests with consequences for species composition and population structures. All four keynote presentations emphasized that tackling of the outlined above ecological challenges requires integration of socio-economic concepts into research rationales.

Most closely related to the conference theme was **Session #2** on "*Indications and Mechanisms of Stress Response in Forest Trees and Ecosystems to Climate Change and Air Pollution*" (CC and AP, respectively). An introductory statement was given by **Rainer Matyssek, Alessandra R. Kozovits and Gerhard Wieser** (WP.701.02), emphasizing a need for improving mechanistic understanding of tree- and forest-level response to CC and associated AP for consistencies *versus* contrasts across hemispheres. To which extent are responses of woody-plants to CC and AP generic, and what conclusions are transferable between hemispheres, given differences in their phenology and growing seasons? Which ecological traits are of prime significance in relation to CC and AP impacts on abundant biodiversity typical for southern hemisphere? Are networking capacities available for integrating particular research needs in the context of CC and AP effects into the trans-hemispheric collaboration?

Such questions were exemplified by highlighting scenarios of most important drivers of global change comprising land-use change as well as the associated CC and AP. Particular consideration was given to main drivers of changes in the southern-hemisphere vegetation: high nitrogen (N) deposition with consequences for biodiversity; groundwater contamination; radiative forcing of the atmosphere including anthropogenic release of CO_2 and AP as ozone formation precursors. Striking is the global consistency between "hot spots" of O_3 exposure and excessive forest burning which counteract ability of vegetation to act as the global carbon sink either by forest destruction or by weakening their capacity of carbon fixation and storage. Intermingled are drought effects with uncertain consequences for ecosystems in the semi-arid regions across subtropics.

Effects of air humidity on tree growth as generated through a free-air humidification approach and modified by further stressors were reported by **Anu Söber et al.** (Estonia) from a perspective of CC in Northern Europe. Growth of trees became reduced under humidification, although mechanisms await clarification, with the effect being inconsistent across species, weather conditions and years. **Karl-Heinz Häberle et al.** (Germany) presented results of another free-air O_3 exposure study with adult European beech and Norway spruce trees at the Kranzberg Forest exploring effects on whole-tree nitrogen (N) acquisition and allocation through ^{15}N labelling. N uptake was reduced under twice-ambient O_3 exposure in spruce rather than beech. The third reported free-air approach pursued atmospheric CO_2 enrichment (**Qiaozhi Mao et al.;** Japan), studying photosynthetic responses of three different larch species. Photosynthetic down-regulation was suggested to result from a dilution effect on needle N pools upon stimulation of needle foliage growth. Visible symptoms and histochemical responses to the oxidative stress by O_3 in native Brazilian tree species as growing in tropical semi-deciduous forests were demonstrated by **Bárbara Baêsso Moura et al.** (Brazil). **Agnieszka Wujeska et al.** (Australia) reported on a meta-analysis of responses by foliar antioxidative and photoprotective defence systems in trees and shrubs to drought. Field experiments revealed stronger responses of defence systems to drought than studies conducted in chambers or glasshouses. Another variant of oxidative stress in trees by heavy metals, as prevailing in soils of semi-deciduous forest remnants in the central-eastern São Paulo State, was presented by **Marcelle Dafré Martinelli et al.** (Brazil). In particular for Ni and Pb, the air-borne pathway of uptake appears to be significant. Hidden carbon sources, involving biogenic volatile organic compounds (BVOCs) emission from a Mediterranean shrubland under progressive water limitation and increasing air temperature, were elucidated by **Carlo Calfapietra et al.** (Italy). BVOC emission *versus* CO_2 assimilation ranged below 0.2 %, with highest levels occurring under drought conditions. **Rosemarie Weigt et al.** (Switzerland) explored concepts of stable isotope analysis in tree rings for identifying physiological mechanisms in response to CC, exemplifying photosynthetic water-use efficiency to increase at low altitude under rising CO_2, whereas at high altitude growth limitations counteract such responses.

Session #1 "*Forest health and changes evaluation*" chaired by **Algirdas Augustaitis** (Lithuania; WP 7.01.01) offered a link to forest sustainability and productivity under the CC and AP conditions. Emphasis was directed to interactions of nitrogenous (N) air pollutants and their deposition as well as surface O_3 exposure, meteorological parameters and various interactive effects on tree-physiological performance and forest stability. European beech and Norway spruce were highlighted as tree species that have become subject of growing concern regarding their ecological and economic importance for adapting to and mitigating harmful effects of CC in combination with AP. Mechanistic understanding of respiratory carbon

fluxes and photo-assimilate allocation was recognized as a crucial pre-requisite for quantitatively modelling global C budgets in reliable ways.

Thorsten Grams et al. (Germany) focused on the allocation of recent photo-assimilates in adult individuals of these two tree species from the canopy to stems, roots and soil respiration, outlining the enormous spatio-temporal dynamics and responsiveness to environmental influences, with deciduous beech proving more O_3-sensitive in stem productivity than evergreen spruce. **Sabine Braun et al.** (Switzerland) showed that foliar phosphorus (P) concentration to decrease drastically in beech between 1984 through 2010 in Switzerland, displaying negative correlation with N deposition, while in spruce the probability of death under drought increased with N deposition when accompanied by foliar K deficiency. **Angelika Kühn et al.** (Germany) confirmed the inherent importance of stomatal regulation under combined O_3/drought scenarios across 10 beech sites in Bavaria on tree productivity, as O_3 uptake was not restricted through stomata at low altitude with ample water supply as contrasting with high altitude under water limitation. **Algirdas Augustaitis et al.** (Lithuania) addressed the limitation of European beech at its NE boundary of natural distribution by consecutive late frosts and summer droughts to be exacerbated through enhanced anthropogenic SO_2 and O_3 regimes. **Rainer Matyssek et al.** (Germany) highlighted the assessment of the stomatal O_3 dose as one risk component by means of tree-level xylem sap flow measurement. For the first time, continuous whole-seasonal and tree-level recordings were presented, yielding high consistency across crown zones, branches and leaves, with O_3-induced stomatal closure counteracting but not preventing high O_3 influx under experimentally enhanced free-air O_3 exposure of adult beech trees. For Mediterranean forests the misleading capacity of AOT40 as a risk index for O_3 impacts was corroborated by **Pierre Sicard et al.** (France), highlighting the FO_3REST project that strives for improved risk assessment standards based on modelled stomatal O_3 fluxes. **Alessandra de Marco et al.** (Italy) reviewed methodological capacities of explaining variation of defoliation as a main indication of forest health and injury in the ICP Forests monitoring program by analysis of climate and soil parameters as well as critical load exceedances of N deposition. **Nancy Grulke** (USA) presented multispectral, high-resolution imagery for differentiating in forest trees between indications of drought stress, bark beetle and pathogen attacks, excessive N deposition, and interactive effects of such agents.

Knowledge gaps regarding mechanisms of conflicting tree responses to N compounds under variable climate change scenarios became apparent during presentations and discussions of Session #1. In particular, interaction with enhanced O_3 regimes demands attention, given continuing trends of increasing ammonia (NH_3) and ammonium (NH_4^+) deposition. This latter aspect was emphasized in **Session #3** on "*Effects of Climate Change and Atmospheric Deposition on Soils and Nutrient Cycling*", chaired by **Mark Fenn** (USA; WP 7.01.03). Given that atmospheric N pollutants in Spain have increased since the 1990s, a study by **Hector García-Gómez et al.** (Spain) on holm oak indicated a large fraction of N to be taken up by the canopy during most of the year. **Andrzej Bytnerowicz et al.** (USA) demonstrated that smoke from forest fires releases large amounts of gases, aerosols and particulate matter (including CO, N oxides and VOCs). These compounds promote O_3 formation downwind of the fires which is favoured by elevated by high temperature and lack of precipitation. Elevated O_3 and deposition of reactive N compounds caused by fires are of concern for air quality and land managers of California montane forests. **Mark Fenn et al.** (USA) highlighted eutrophication from N deposition to impose greater risk to the *Pinus banksiana* stands in northern Alberta, Canada, than does the associated acidification. A novel approach was proposed by **Viktor J. Bruckman et al.** (Austria) for mitigating impacts of N deposition

(primarily by aerosols transported from China) on mycorrhizal fungi in the *Quercus crispula* stands in Japan. Application of biochar can induce a liming effect to soils and buffer acidification caused by elevated N input. **Márcia Lopes et al.** (Brazil) reported on forest soils showing fertilization by urban emissions in the Metropolitan Campinas Region (Sao Paulo state) at pH 4.5, with lowest pH of 3.6 being reached under industrial pollution. In Scandinavia, increasing temperature-driven bedrock weathering may counteract base cation loss due to tree harvesting that includes crown biomass withdrawal. Climate modelling by **Cecilia Akselsson et al.** (Sweden) predicts increased base cation weathering by up to 33 % until 2050 with largest proportional increase occurring in the north.

The multi-factorial impacts of CC and AP were presented in **Session #6** chaired by **Nancy Grulke** (USA; WP 7.01.06) "*Multiple stressor effects on forest ecosystems and ecosystem services*". **Mikhail Kozlov et al.** (Finland) comprehensively reviewed the state of (limited) knowledge on background foliar herbivory in woody plants in view of new data from five S-N transects in Norway, Finland, and Russia. He pointed to a fact that excess of 8 % of foliage area loss reduces both the radial and height growth of trees. Under cool climate, foliage area herbivory increased by 2 % per each degree of geographical latitude towards south, although increasing temperature had no effect in warm climate. **Takayoshi Koike et al.** (Japan) addressed ectomycorrhizal (ECM) richness and growth of hybrid larch under experimentally elevated CO_2 and O_3 exposure, proving differential sensitivity of fungal species across six ECM types. Whole-plant biomass production was ranked, from higher to lower, by the treatments $+CO_2$ > $+O_3/+CO_2$ > control > $+O_3$. **Carlo Calfapietra et al.** (Italy) used the eddy covariance methodology to evaluate potential of urban forests to absorb both O_3 and particulate matter in a context of their effects on net C and water fluxes to tree canopies. Differential effects resulted from size of particulate matter; upper and lower tree crowns; as well as under winter or summer conditions. **Rocìo Alonso** et al. (Spain) presented responses of understory species of Holm oak forests to combined elevated O_3 and excess N regimes. Nitrogen amendments partially mitigated limiting effects of moderate O_3 exposure on live biomass although also enhanced soil N_2O and NO emissions and soil respiration. These factors together with reduced net ecosystem CO_2 exchange decreased gross primary productivity of the studied ecosystem and caused shifts in species community composition. Indicator capacities of vegetation and lichen functional groups were explored by **Cristina Branquinho et al.** (Portugal) along a gradient of land degradation, desertification, and eutrophication from sub-humid towards semi-arid ecosystems. Lichens of the Mediterranean oak woodlands were highly N-sensitive, as plant diversity increased with precipitation, although grasses gained in dominance towards the driest sites. **Algirdas Augustaitis et al.** (Lithuania) reported on differential tree species responsiveness to multiple stressors. Norway spruce was more resistant than Scots pine to excessive N supply but its recovery was retarded. Siberian larch had highest resistance to extreme frost temperatures and high N deposition.

Session #4, chaired by **Om P. Rajora** (Canada; WP 7.01.04) dealt with "*Genetic Aspects*" of CC and AP effects on forest trees and ecosystems. Given the cancellation of the originally announced contributions, **Om P. Rajora** presented an extended overview o structural, functional and population genomics and bioinformatics for unravelling molecular genetic mechanisms underlying tree response and adaptation to CC and AP. Highlights were exemplified from his research on natural selection and local adaptation of red spruce (*Picea rubens*) in response to sulfate air pollution, differential gene expression in black spruce (*Picea mariana*) in response to CC conditions, and identifying and genome mapping of quantitative trait loci underlying growth and ecophysiological adaptive traits. Presented

approaches can provide powerful tools and technologies for identifying indicators and biomonitors of ecosystem processes and dynamics, and assist in conservation and sustainable management of forest resources under changing environment. The interdisciplinary nature of IUFRO 7.01.00 was distinguished as being an optimal platform for the demanded integration of genetic and genomics aspects in holistic ecosystem research concepts.

Yusuf Serengil (Turkey; WP 07.01.07) chaired **Session #7** "*Water, Watersheds and Climate Change*". In his introductory remarks the chairman underlined the progressive scarcity of freshwater resources under the increasing pressure by the globally advancing overpopulation. Concerns on availability of water were exemplified, in particular, by expanding drought in many parts of the world. At the watershed level, the challenge of constructing a conceptual framework that links ecophysiological responses with local water cycling was stressed. Complexity and understanding of forests in their functionally adaptive and stress-absorbing entirety require research to address open systems for studying environmental interaction. ForSAFE model was presented by **Zanchi et al.** (Sweden) as an integrated biogeochemical model (comprehending tree productivity, nutrient cycling and atmospheric deposition and weathering) that transfers ecosystem-scale input to watershed-scale output, exemplifying effects of forest management practices. Hydrological ecosystem-scale studies were suggested in support of watershed models that bridge towards micro-scale site investigations. Comparisons by **Pamukcu et al.** (Turkey) in the Marmara region between land-use change and CC demonstrated stability in runoff characteristics, although additive effects were indicated in influences on water resources. **Leite & Fujaco** (Brazil) suggested that drying-out of Brazilian creeks results from CC in combination with the conversion of natural vegetation into eucalypt plantations. Ecosystem-level carbon stock formation *versus* build-up of water storage capacities is a conflict between various ecosystem services and matter of their optimization. **Serengil et al.** (Turkey) discussed how land use change, including forests, may affect provision of water as the ecosystem service. To cope with potential conflict between various ecosystem services there is a need for their optimization. This can also be handled quite efficiently in watershed scale especially if water production is significant; however, a major challenge of optimization is the quantification of the services.

The evidence-integrating capacity of modeling was stressed in **Session #5**, chaired by **Salim Belyazid** (Sweden; WP 7.01.05) through the topic "*Uncertainties and confidence of modeling tools in risk assessment of ecosystem responses to changing environmental conditions*". O_3 uptake and effects on tree growth, stomatal conductance, absorption of solar radiation, and tree health in general were discussed. The DO_3SE model and FO_3REST project were shown as an example for merging empirical and modelling information for advancing mechanistic understanding of ecosystem processes. **Silaghi et al.** (Romania) pointed out the sensitivity of modelling O_3 uptake in plants to soil moisture, as water availability from deep soil horizons promotes plant-level O_3 uptake, so that vertical aggregation of soil moisture is crucial for accurately modelling stomatal O_3 flux. **Hoshika et al.** (Japan) argued for differentiating in modelling O_3 uptake between sun-exposed and shaded leaves is a supplementary factor that accounts for sun-exposure vs. shadiness. **De Marco et al.** (Italy) demonstrated the DO_3SE model to yield accurate estimates when used with site-specific phenological parameters describing the actual vegetation at the study site. It was concluded that in general modelling O_3 uptake and its effects on tree growth does profit from the use of site-specific input of pedological and phenological data by preventing erroneous prediction of O_3 fluxes and the associated plant responses.

The "*Pot Pourri*" **Session #8** was chaired by **Andrzej Bytnerowicz** (USA; IUFRO 7.01.00). **Chen et al.** (China) addressed responses of the radial stem growth of trees to CC at the timberline in the SE Tibetan Plateau, highlighting differences between the shade-tolerant and intolerant tree species. **Brito et al.** (Spain) stressed the importance of the hydrological year when considering influences of drought on canopy transpiration of *Pinus canariensis* at treeline sites of the Tenerife Island.

The compilation of scientific topics from various studies world-wide that were addressed during eight sessions of this biennial conference have appeared to be a promising initiation of the future trans-hemispheric collaboration envisaged within RG 7.01. For future conferences, researchers were encouraged to contribute research findings on concurrent, multiple-stressor effects on forest trees and ecosystems.

1.2. General conclusions from the conference

Highly diverse woody-plant ecosystems of southern hemispheric are undergoing extreme anthropogenic pressure from rapid population growth and associated land-use changes & industrialization. Consequences of ecosystem fragmentation and loss are poorly understood as functionalities of most of the residual ecosystems await clarification. Combined effects of changes in land-use, climate and air pollution on forests are complex. Inclusion of a socio-economic dimension is essential for better understanding of changes at the ecosystem and landscape scales. Globally-integrated research networks are needed to find generalities in ecosystem functionalities required for effective mitigation of impacts of multiple stressors.

1.3. Outlook and future research directions

It was recognized that the major conclusions from the sessions and conference as a whole were consistent with the rationale of a book recently published by members of the IUFRO RG 7.01.00 actively participating in the European COST Action FP0903 "MAFor" (Matyssek et al., 2013a).

The Elsevier book (Matyssek et al., 2013a) and the scientific discussions of the Ilheus conference conclude that a comprehensive understanding of forest ecosystem functioning under CC and AP can be best achieved through integration of empirical research, monitoring and process-based, large-scale modelling. The concept developed in the Elsevier book proposes an establishment of a global network of well-instrumented "**Supersites in Forest Research**". Transcontinental collaboration networks interlinking supersites are envisaged to extend across both hemispheres, with a proposed time horizon of one decade to get such network established for initial long-term research. Our concept envisions integration of the already existing research sites and new ones established globally across the ecologically relevant biomes (Fig. 6)

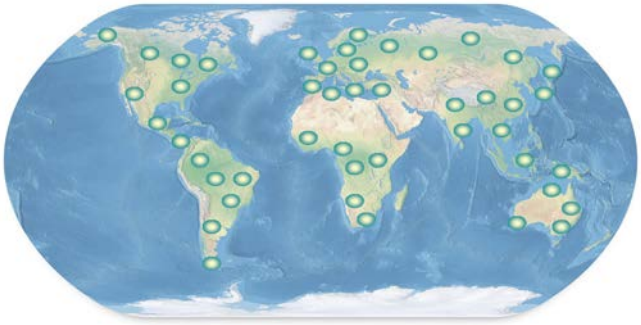

Fig. 6: Planned global network of "Supersites in Forest Research" with preliminary regional locations according to biomes of globally putative ecological relevance (see text and Matyssek et al. 2013a).

Exchange of expertise and methodological innovations will initiate global scientific networking to explore consistency in forest ecosystem responses to climate change and air pollution across the hemispheres. Potential risks to health, biodiversity and sustainability of natural and cultivated forests in South America need to be explored. Such assessment will provide a basis for fostering mitigation concepts of anthropogenic stress impacts focusing on forests and other woody-plant ecosystems (e.g., in Brazil, on Amazonian and Atlantic rain forests or cerrado vegetation). It is of crucial importance since at a global level these ecosystems have the highest potential to sequester increasing CO_2 concentrations and counteract climate warming and extending droughts.

2. Elsevier COST Program book

Several RG7.01 officers contributed to a recent book on the interactions among climate change, air pollution and forests (Matyssek et al., 2013a). The state of knowledge evaluated in the book provides ample arguments for integrating experimentation, long-term monitoring and modelling so as to provide meaningful science-based management guidelines and certification systems for forest adaptation to a changing environment. An important improvement of the existing forest monitoring and research infrastructures can be obtained by combining long-term experiments with ecosystem level monitoring and with modelling. To that end, the establishment of a Supersite concept is recommended. This means that independent funding mechanisms for the infrastructures and for data evaluation as well as evaluation of the legal framework are required.

It will be important to cross-compare data from different databases in order to develop advanced use of present data, including validation and new development of models and understanding of real-world forest responses to air pollution and climate change. There is still a need of improving links between monitoring of atmospheric changes and impacts on forests because these two fundamental activities are usually carried out separately in independent research networks. The creation of a transnational system of Supersites for forest monitoring and research can only be achieved if scientists from different disciplines and managers from different existing networks are involved. Three demands have to be met: (i) unifying the scientific communities of experimentalists, monitoring experts and modelers to work on the same sites in joint interdisciplinary research programs; (ii) designing monitoring and research to analyze the unity of process interaction between vegetation, atmosphere and soil; (iii) establishing networks of Supersites across continents, that is, within and between hemispheres, through global harmonization of research programs.

Supersites have the potential to fill the gaps and provide scientifically sound knowledge for forest protection and adaptive management in a changing world, but this requires coordination, harmonization and a joint long-term platform for data exchange and modelling. The aim is to develop and validate large-scale and long-term models, in order to enable reliable risk assessment and provide prerequisites for sound policy development. Key topics for consolidating process-based knowledge are ecosystem-level carbon sequestration and storage, soil chemistry and water budgets, with major emphasis on mechanisms of soil–vegetation–atmosphere CO_2 exchange, BVOC and aerosol turnover, O_3 formation and uptake, and N deposition as related to woody-plant and ecosystem performance. Science-based approaches for addressing future risks and challenges to forests require close collaboration

among the communities operating monitoring and research networks as well as experts in process and large-scale modelling.

3. Other IUFRO related activities

Andrzej Bytnerowicz, Coordinator of RG 7.01.00 participated in the IUFRO Extended Board meeting as its Member and a Deputy Coordinator of IUFRO Division 7 "Forest Health". As a result of that meeting he was charged with developing a document IUFRO strategy on Climate Change for 2014-2019. Draft of a stategy document has been prepared by a team of authors from various IUFRO units (Andrzej Bytnerowicz, Markku Kanninen, Eckehard Brockerhoff, Andrew Liebhold, Daniela Kleinschmit, and Elena Paoletti). This document has been submitted to IUFRO Board for a review.

Andrzej Bytnerowicz, also co-chaired a scientific session "Threats to Forest Health – Forest Pests and Diseases, Biological Invasions, Air Pollution and Climate Change". At that session he presented a paper "Interactive Effects of Air Pollution and Climate Change on Forests in the United States" which has been developed based on collaboration with the US Forest Service and university colleagues.

4. Selected important publications

Matyssek, Clarke N., Cudlin P., Mikkelsen T.N., Tuovinen J.-P., Wieser G., and Paoletti E. eds. 2013a. Climate Change, Air Pollution and Global Challenges: Understanding and Perspectives from Forest Research. Elsevier Physical Sciences Series "Developments in Environmental Science", 13, 622 p, http://cost-fp0903.ipp.cnr.it/).

Matyssek, R., Lüttge, U., Rennenberg, H., eds. 2013b. The Alternatives Growth and Defense: Resource Allocation at Multiple Scales in Plants. Nova Acta Leopoldina, pp. 369

Bashalkhanov, S., A. J. Eckert, and O.P. Rajora. 2013. Genetic signatures of selection in response to air pollution in red spruce (Picea rubens, Pinaceae). Molecular Ecology 22: 5877–5889. Doi: 10.1111/mec.12546.

Kozak, J., Ostapowicz, K., Bytnerowicz, A., Wyzga, B. eds. 2013. The Carpathians: Integrating Nature and Society towards Sustainability; Environmental Science and Engineering, Springer, Berlin, 722 p.
http://www.springer.com/environment/nature+conservation+-+biodiversity/book/978-3-642-12724-3

Special sections in scientific journals containing publications based on the IUFRO RG. 7.01.00 biennial conference in Kaunas, Lithuania (2012): "Biological Reactions of Forest to Climate Change and Air Pollution":

a. *"The iForest", 9 papers, Elena Paoletti, Andrzej Bytnerowicz, Algirdas Augustaitis (Guest Editors), http://www.sisef.it/iforest/archive/?action=browse&by=coll&arg=1*

b. *"Environmental Pollution, 5 papers from the IUFRO RG. 7.01.00 biennial conference in Kaunas, Lithuania (2012): Introduction Pages 657-658 by Algirdas Augustaitis, Andrzej Bytnerowicz, Elena Paoletti, http://www.sciencedirect.com/science/journal/02697491/184*

c. *"European Journal of Forest Research", additionally presenting a "Special Topic" on the IUFRO RG. 7.01.00 biennial conference in Kaunas, Lithuania (2012) with nine papers including an editorial by Rainer Matyssek, Alessandra R. Kozovits, Gerhard Wieser, Ingrida Augustaitiene, Algirdas Augustaitis (2014), DOI 10.1007/s10342-014-0803-9); http://link.springer.com/article/10.1007/s10342-014-0803-9.*

5. Honors

In 2013, Rainer Matyssek, Coordinator of WP 7.01.02 was appointed a member of the honourable Deutsche Akademie der Naturforscher *Leopoldina* - Nationale Akademie der Wissenschaften (German National Academy of Sciences, Leopoldina).

In 2014, Om Rajora, Coordinator of WP 7.01.04 has been awarded Indira Foundation Distinguished Visiting Fellowship to develop genetics and genomics research programs addressing sustainable development at TERI University, New Delhi, India.