ICP Forests

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Forest Condition in Europe
2017 Technical Report of ICP Forests

Report under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)

Alexa Michel & Walter Seidling (Eds.)

LRTAP
Long-range Transboundary Air Pollution

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Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

BFW
Bundesforschungszentrum für Wald

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We especially wish to thank all participating countries in ICP Forests that have provided data and their national report. For a complete list of all countries that are participating in ICP Forests with their responsible Ministries and National Focal Centres (NFC), please refer to the annex. We also wish to thank the ICP Forests community for their valuable comments on draft versions of this report and Mr Ferdinand Kristöfel and the Austrian Research Centre for Forests (BFW) for its publication.

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http://icp-forests.net

LRTAP Long-range Transboundary Air Pollution
ICP Forests

wge Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

SUMMARY

The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is one of the most diverse programmes within the Working Group on Effects (WGE) under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). To provide a regular overview of the programme's activities, the ICP Forests Programme Co-ordinating Centre (PCC) yearly publishes an ICP Forests Technical Report which summarises research highlights and provides an opportunity for all participating countries to report on their national ICP Forests activities. The PCC also invites all ICP Forests Expert Panels, Working Groups, and Committees to publish a comprehensive chapter on their most recent results from regular data evaluations.

This 2017 Technical Report presents results from up to 32 of the 42 countries participating in ICP Forests. Part A presents **research highlights from the 2016/17 reporting period**, including:

- a review of this year's **32 scientific publications** for which ICP Forests data and/or the ICP Forests infrastructure were used;
- a summary of the **5th ICP Forests Scientific Conference** in Luxembourg in May 2016;
- a list of all **49 ICP Forests research projects** ongoing for at least one month between June 2016 and May 2017.

Part B focuses on **regular evaluations** from within the programme. This year the Technical Report includes chapters on:

- the spatial variation of **atmospheric throughfall deposition** in forests in Europe in 2015;
- trends in foliar **nitrogen and phosphorus foliar concentrations and element ratios** since 2000;
- **tree crown condition** in 2016 including trend analyses;
- selected **meteorological stress indices** for 2013–2015.

Part C includes **national reports on ICP Forests activities** from the participating countries.

For contact information of all authors and persons responsible in this programme, please refer to the annex at the end of this report. For more information on the ICP Forests programme, please visit the ICP Forests website[1].

Summary of the presented results from regular evaluations in ICP Forests (Part B)

Monitoring the **atmospheric deposition to forests** is a prerequisite for understanding forest ecosystem processes and an important contribution for evaluating the spatio-temporal trends of air pollution. In this report the annual throughfall deposition of eutrophying, acidifying and buffering components on ICP Forests Level II plots in 2015 is presented. It must be noted, however, that the total deposition to forests is typically higher by a factor of 1 to 2 than the throughfall deposition measured under the forest canopy.

The nitrogen (N) compounds nitrate (NO_3^-) and ammonium (NH_4^+) are the main drivers of eutrophication and also contribute to acidification. High throughfall deposition rates to forests (throughfall deposition > 8 kg N ha^{-1} yr^{-1}) were measured at several plots in central Europe (Belgium, Germany) but also in the

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[1] http://icp-forests.net

Czech Republic, Denmark and southern Sweden. Low throughfall deposition rates were reported primarily for northern Europe.

Sulfate (SO_4^{2-}) has been the most important driver of soil acidification. High throughfall deposition of SO_4^{2-} (> 8 kg SO_4^{2-}-S ha^{-1} yr^{-1}) was still found in central and southern Europe (Belgium, Germany, Czech Republic, Italy, and Greece).

Calcium (Ca^{2+}) throughfall deposition was high across southern Europe, likely related to contributions from Saharan Dust. The spatial pattern of magnesium (Mg^{2+}) deposition is mainly dominated by marine sources. Both $Ca^{2+}$and Mg^{2+} are macronutrients and act as buffers against acidification.

The overall spatial patterns of throughfall deposition in 2015 remained similar to results from the previous years.

Analyses of the chemical composition of leaves and needles over time and space allow the identification of trends and spatial patterns of the nutritional state of single trees and forest stands. Both, the **levels and trends of foliar nitrogen (N), phosphorus (P), and the N:P ratio** of the tree species European beech (*Fagus sylvatica*), Norway spruce (*Picea abies*), and Scots pine (*Pinus sylvestris*) were analysed. Average concentrations a decade ago (2000– 2005) were compared with recent values (2010 –2015) while trends were analysed for the overall period 1993 to 2015.

A declining trend in foliar P concentrations was found in European beech and Norway spruce, indicating an increasing P limitation of trees and forest stands. Foliar P concentrations were, however, relatively stable over the years in Scots pine. With regard to foliar N concentrations, the results suggest that the supply is at least adequate on the majority of the observed Level II plots for *Fagus sylvatica* and *Pinus sylvestris*, while a larger proportion of *Picea abies* plots remains in the deficiency range. The N:P ratio in all three species increased during 1993–2015.

The chapter on **tree crown condition** presents results from the assessments carried out on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests in 2016, as well as long-term trends for the main species and species groups.

In 2016, the average crown defoliation in the participating countries was 22.1% for broadleaved and 20.1% for conifer species. For most species, it remained largely in the range of observations from previous years. However, the defoliation of Scots pine, which generally does not deviate much from the trend, was higher in 2016 than the long-term mean, and the defoliation of Norway spruce remained on the level above the long-term trend for the third consecutive year. For Norway spruce especially, a large share of damage symptoms could not be assigned to specific damage agents, complicating the interpretation of defoliation assessments. After several years of improved crown condition, the defoliation of beech increased to the highest value ever recorded. The most common identified causes of damage on beech in 2016 were mining insects and defoliators. Mediterranean lowland pines showed the strongest trend in defoliation (around 3% every 10 years) while the highest mean defoliation in 2016 was observed in evergreen oaks (25.0%).

The average number of recorded damage symptoms per assessed tree was lower for the conifer species or species groups (on average 0.5 symptoms per tree in Norway spruce, Austrian pine, Mediterranean lowland pines and Scots pine) than for broadleaved species (on average 0.9 symptoms per tree in common beech, deciduous (sub-) Mediterranean and temperate oaks and evergreen oaks). Insects, abiotic causes and fungi were the most common damage agent groups, comprising altogether more than half (54.9%) of all damage records.

Climatic conditions significantly affect forest ecosystems and the inherent biogeochemical processes and relationships in the system of soil, plant and atmosphere. In a changing climate, the observation and analysis of long-term climatic conditions and solely weather events is crucial to evaluate and rank the processes and changes observed in the different surveys of the ICP Forests monitoring programme. This chapter reports on **values of stress indicators related to specific weather conditions across Europe of the years 2013 to 2015** and identifies spatial patterns and relationships for such weather events. Despite the short study period of this evaluation, substantial differences in the meteorological stress indicators values were found between plots across Europe. Therefore, it is crucial that climatic conditions be considered when evaluating the results of other surveys since significant differences in meteorological variables may be responsible for significant changes in forest ecosystems.

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PART B – REPORTS ON INDIVIDUAL SURVEYS IN ICP FORESTS

PART C – NATIONAL REPORTS

ANNEX

1 INTRODUCTION

Alexa K Michel, Walter Seidling[1]

The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 with the aim to collect, compile, and evaluate data on the condition of forest ecosystems across the UNECE region and monitor their condition and performance over time. ICP Forests is led by Germany, and its Programme Co-ordinating Centre is based at the Thünen Institute of Forest Ecosystems in Eberswalde. It is one of eight subsidiary bodies (six ICPs, an additional Task Force, and a Joint Expert Group) that report to the Working Group on Effects (WGE) of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) on the effects of air pollution on a wide range of ecosystems, materials, and human health.

ICP Forests monitors forest condition at two monitoring intensity levels: The Level I monitoring is based on around 5600 observation plots (as at 2016) on a systematic transnational grid of 16 x 16 km throughout Europe and beyond to gain insight into the geographic and temporal variations in forest condition while the Level II intensive monitoring comprises around 600 plots (as at 2015) in selected forest ecosystems with the aim to clarify cause-effect relationships between environmental drivers and forest ecosystem responses. Quality assurance and quality control procedures are co-ordinated by committees within the programme and the ICP Forests Manual[2] ensures a standard approach for data collection in forest monitoring among the 42 participating countries.

Programme highlights in 2016/17

In January 2017 **Dr Marco Ferretti was nominated as new Chairman of ICP Forests** following Prof Dr Michael Köhl who had resigned after 11 years in this position.

Every year several of the ICP Forests Expert Panels and Working Groups meet to discuss recent activities and future developments in their field. At the latest combined **Expert Panel Meeting**, international experts involved in ICP Forests in the fields of ambient air quality, crown condition and damage causes, deposition, foliar and litterfall, soil and soil solution, and quality assurance and quality control in laboratories met in Zagreb on 27–31 March 2017. For more information on this event and its results, please refer to the ICP Forests website[3].

Other important activities of ICP Forests since the 2016 Task Force Meeting include the online publication of the new ICP Forests Manual, the start of a new collaborative data analysis together with colleagues from the ICP Integrated Monitoring, the introduction of ICP Forests briefs as a new reporting medium, and new developments of the data unit.

- The **ICP Forests Manual** was updated (except Parts I and II) and published on the ICP Forests website and has replaced the version from 2010.
- New collaborative data analyses within the WGE have started involving experts from ICP Forests and **ICP Integrated Monitoring**.

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[1] For contact information, please refer to the annex.

[2] http://icp-forests.net/page/icp-forests-manual

[3] http://icp-forests.net/events/icp-forests-expert-panel-meetings-zagreb

- The new **ICP Forests Brief** is a new regular publication to inform policy makers and the general public in a very clear and concise way about important findings from the programme and to provide policy recommendations to help maintain forest ecosystem integrity in the UNECE region.
- The **data unit** at the Programme Co-ordinating Centre (PCC) of ICP Forests is constantly improving the data management, data availability and usability, and information flow within the programme and to the scientific community and the public. The following developments of the data unit were recently accomplished:
  - A **versioning concept** has been added to the online documentation[1] of the collaborative database to allow users to identify changes which have to be known to guarantee high data quality.
  - Data submitted to the collaborative database of ICP Forests such as **photos or data accompanying reports** in addition to the standardized forms are now available for the first time for any user. This file archive represents a great source of additional information for the community.
  - At present the data portal of ICP Forests is further developed towards a **more practical and user-friendly data submission**.

For more than 30 years the success of ICP Forests depends on the continuous support from 42 participating countries and the expertise of many dedicated individuals. We would like to hereby express again our sincere gratitude to everyone involved in the ICP Forests and especially to the participating countries for their ongoing commitment and co-operation in forest ecosystem monitoring across the UNECE region.

The 2017 Technical Report of ICP Forests and other information on the programme can be downloaded from the ICP Forests website[2]. Please send your comments and suggestions to pcc-icpforests@thuenen.de; we highly appreciate your feedback.

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[1] http://www.icp-forests.org/documentation/

[2] http://icp-forests.net/page/icp-forests-technical-report

Part A

ICP Forests research highlights
June 2016 – May 2017

2 REVIEW OF ICP FORESTS PUBLICATIONS (06/2016–05/2017)

Anne-Katrin Prescher, Andreas Schmitz, Alexa K Michel[1]

Between June 2016 and May 2017, data that had either originated from the ICP Forests database or from ICP Forests plots were part of several international, peer-reviewed publications in various research areas, thereby expanding the scope of scientific findings even beyond air pollution effects. The following review includes all 32 English online and in print publications that have been reported to the ICP Forests Programme Co-ordinating Centre and added to the list of ICP Forests publications on the programme's website[2]. For a general overview of the findings in different research areas, this year's publications have been assigned to five sections:

- carbon fluxes and carbon sequestration;
- nutrient dynamics and interactions;
- climatic and management effects;
- up-scaling and remote sensing;
- ecological methodology and modelling.

Publications already listed in the previous 2016 Technical Report are not again included. For a list of all 32 ICP Forests publications in this reporting period, please refer to the end of this chapter.

Carbon fluxes and carbon sequestration in forest ecosystems

The carbon cycle, drivers of carbon fluxes, and methods of carbon budgeting in European forest ecosystems have been part of several publications. Two studies focussed on the evaluation of soil organic carbon (SOC) by measurements and modelling. The review paper of **Vanguelova et al. (2016)** gives a detailed summary about the systematic errors and uncertainties associated with the SOC evaluation for five scales: sample, profile, plot, landscape and European scale. They found that the inaccurate quantification of soil bulk density, fragment content and complete soil profile depth are at all scales sources of error in SOC estimation, but also scale-dependent uncertainties have to be considered. To validate a SOC modelling approach, **Lehtonen et al. (2016)** evalutated the soil carbon model Yasso07 and the soil organic matter decomposition model ROMULv against the soil carbon stock measurements of the BioSoil data set. Their results show that models that only consider litter quality, litter quantity, and weather data underestimated soil carbon stocks in Southern Finland. Therefore, Lehtonen et al. (2016) point out the necessity of improved greenhouse gas inventory methods and soil modules of Earth system models by considering soil texture and soil moisture on decomposition.

Further, several publications focussed on the temporal change of dissolved organic carbon in soil solution (DOC) and its drivers. **Camino-Serrano et al. (2016)** investigated the long-term trends in soil solution DOC and their physico-chemical and biological drivers in a Europe-wide study. They found that 40% of European plots showed no significant trend, 35% of plots showed a significant increase and 25% of plots showed a significant decrease in soil solution DOC concentrations, indicating that interactions between local and regional controls are more relevant for soil solution DOC trends than mechanisms valid for the whole of Europe. On the plot scale, **Sawicka et al. (2016)** studied the temporal change of soil solution chemistry and potential drivers of DOC production at different plots in the UK. The determined trends in soil solution DOC concentration were found to be non-linear, and magnitude and

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[1] For contact information, please refer to the annex.

[2] http://icp-forests.net/page/publications

sign of the trends were related to changes in acid deposition, the presence of a forest canopy, soil depth and soil properties. In a second paper, **Sawicka et al. (2017)** used the dynamic soil chemistry model MADOC to determine the effect of decreased deposition of sulphate and chloride, accumulation of reactive N, and higher temperatures, on soil solution DOC. The results of this study suggest that future DOC concentrations might exceed preindustrial levels as a consequence of nitrogen pollution.

The carbon sequestration rate of French forest soils was determined by **Jonard et al. (2017)**. Using the results of soil surveys, they determined a significant increase in SOC stock in the forest floor and in the 0-10 cm mineral layer. In general, this increase equalled 0.35 MgC ha-1 yr-1 (0-40 cm). Due to the continuous measurement of the relevant variables on ICP Forests plots, the driving factors of the estimated SOC change could be tested.

Nutrient dynamics and interactions with the forest ecosystem

Next to carbon, fluxes and the effects of different nutrients (N, P, S) and heavy metals on forest ecosystems have been subject to a range of publications.

Most studies focus on the atmospheric deposition of nitrogen and sulphur. In several studies, the current levels and variability of deposition in space and time have been analysed. Based on long-term data from 15 sites and 43 sites, **Hunova et al. (2017)** analysed the temporal trends and spatial patterns of wet N deposition, respectively, with respect to its reduced and oxidized forms for Czech forests. Regarding temporal trends in precipitation, a statistically significant decrease was found at 12 sites in NO_3^- and at 5 sites in NH_4^+. Changes in spatial patterns of wet atmospheric deposition showed that the $N\text{-}NH_4^+/N\text{-}NO_3^-$ ratio has been slowly changing in favour of NH_4^+. The trends in atmospheric deposition chemistry in France were analysed by **Pascaud et al. (2016)** using data from three monitoring programs including ICP Forests, but not coupled with a model. On a smaller scale, **Kowalska et al. (2016)** investigated the effect of four tree species in coniferous and deciduous tree stands in Poland on the amount and chemical composition of precipitation during the canopy passage to the soil.

Another part of the publications based on ICP Forests deposition data dealt with the effects of deposition on various aspects of forest ecosystems. **Meesenburg et al. (2016)** analysed in which way important forest ecosystem properties like acidification, eutrophication and tree nutrient availability reacted over long-term to changes in deposition levels. Based on Level II data from about 20 countries, **Van Dobben & De Vries (2016)** studied the response of understory vegetation to different stressors, finding that in addition to climate and soil, nitrate deposition is a significant determinant of forest ground vegetation. **Novotný et al. (2016)** found an increase in the occurrence and cover of nitrophilous species in the herb layer from 1995 to 2006 in 25% of the 154 analysed Czech ICP Forests plots, which corresponded to the found increase of total nitrogen in forest soil during that time period.

Next to nitrogen and sulphur deposition, the atmospheric deposition of heavy metals is also a threat to forest ecosystems. To evaluate the resistance of lichen species to atmospheric metal pollution a new approach was used by **Agnan et al. (2017)** in coupling lichen diversity and metal bioaccumulation in a multivariate analysis. Using samples from seven French and one Swiss remote forest site, they introduced a new resistance scale to distinguish between sensitive, intermediate and resistant species for 43 most frequent lichen species. In addition, they found that lichen abundance was a better indicator of metal pollution than the index of atmospheric purity.

In addition to nitrogen, phosphorus (P) is an essential plant nutrient. Since phosphorus is very scattered in forest soils and preferential flow pathways are the main way of nutrient transport, the composition of phosphorus in preferential flow pathways (PFP) and the soil matrix was studied by **Julich et al. (2016)** at four German Level II plots. They measured labile and total P, finding that their ratio was significantly lower in P-rich soils compared to P-medium and P-poor soils. Further, contents of labile and moderately labile P were different for PFPs and soil matrix, but this difference was not statistically significant. However, they found indications for an accumulation of labile organically bound P in PFPs.

In addition to publications directly based on ICP Forests data, studies based on the ICP Forests Manual and methodologies are also published. For example, **Bezlova et al. (2016)** determined the heavy metal concentrations (Cu, Zn, Pb and Cd) in conjunction with the ICP Forests Manual (2010) in beech leaves at eight sites in the Central Balkan National Park which are by definition not part of the ICP Forests monitoring network.

Climatic and management effects on forest ecosystems

Climatic conditions are driving most biogeochemical processes in forest ecosystems. The effect of climate and atmospheric processes on tree defoliation was studied by **Sánchez-Salguero et al. (2017)** at Spanish ICP Forests plots. They found that enhanced defoliation was related to warmer and drier conditions in April that were linked to high values of the Atlantic Multi-decadal Oscillation. Their results indicate that large-scale links between atmospheric processes and defoliation patterns exist.

Temperature driven phenological traits as leaf unfolding and leaf senescence were studied by **Delpierre et al. (2017)** based on a French phenological database covering 5 years of individual tree observations in different European Beech, Sessile Oak and Common Oak stands. Within one population, individual phenological ranks repeated from year to year among trees with higher repetition in spring traits than in autumn traits. They found correlations between individual tree growth and their phenological ranks in all three tree species. The variability of phenological rank repetition observed across populations was suggested to be affected by the water availability within a population.

Fernández-Martínez et al. published two papers regarding the impact of productivity and climate on fruit production in European forests. **Fernández-Martínez et al. (2017)** used litterfall and foliar nutrient concentration from 126 European forests to study the effect of prodctivity and climate on fruit production. They found that on average 0.5 to 3% of gross primary production were allocated to reproduction, with higher maximum fruit production and the interannual variability in Fagaceae than in Pinaceae species. Regarding nutrient concentrations, foliar P and Zn concentrations were found to be positively correlated to fruit production. The effect of the North Atlantic Oscillation on the patterns of fruit production across western Europe was highlighted in **Fernández-Martínez et al. (2016).** They found a significant relationship between the interannual variability of fruit production and seasonal NAO indices, but synchrony of fruit production was mainly related to weather and geographical distance between the forests.

The effect of management on forest ecosystems was also assessed in several studies. The impact of cutting on forest understory vegetation was studied by **Tonteri et al. (2016).** They evaluated the drivers of temporal change in the cover of boreal forest plant species in Finland, focusing on the effect of regeneration cuttings and intermediate cuttings on 11 different understory species. They found that regeneration cuttings generally resulted in an increase in early successional light-demanding species and in a decrease in late successional shade-tolerant species, and that intermediate cutting favoured all but the most light-demanding species. In Finland, cutting was found to be the main driver of temporal vegetation change rather than a changing climate.

The effect of coppicing and how foresters chose to coppice on flora diversity was analysed by **Cervellini et al. (2017)** for selected 57 forest plots in the Central-Italian Apennines. Using vegetation surveys, interviews with loggers and forestry service officials, and questionnaires, they concluded that after allowing regeneration of stumps and the regrowth beyond a certain diameter, economically feasible coppicing can occur. This results in favorable understory conditions for forest specialist plants to re-establish and makes the present coppicing regime compatible with conservation of the diversity of these species in the forest (**Cervellini et al. 2017**).

Up-scaling and remote sensing

In general, ICP Forests data are point or plot measurements that have to be up-scaled for regional, national or global evaluations. **Noce et al. (2016)** combined spatial analyses and statistical procedures using geographic information systems to identify forest community hot spot priority areas. The methodology is based on quantitative maps of forest distribution determined from Level I data. Their results for selected species of the Mediterranean Basin point out that the quantity and quality of information determined from existing forest distribution maps can be increased by their methodology.

Instead of up-scaling terrestrial stem diameter and height measurements of selected trees, it seems likely that tree crown height and diameter could be derived from high resolution remote sensing data for all trees in larger areas. The question how to use such remote sensing to directly gain a tree and biomass inventory of forests was addressed by **Jucker et al. (2016).** For that, they compiled available tree measurements worldwide and developed general allometric models to estimate the stem diameter and biomass of trees from tree height and crown diameter with a confidence interval ranging from about -50% to +80% of the value for diameter and from about -75% to +300% for biomass. However, their estimates are often biased at regional and smaller scales, because trees within a forest often tend to deviate in a similar direction. Next to other sources, ICP Forests data was used for their large input data set. **Glick et al. (2016)** set the first spatially-explicit model of global tree density using ICP Forests plots as part of 420,000 forest inventory plots. Using their spatial data products, the number of trees can be estimated precisely at a global or biome scale, but should not be used for local estimations.

The fraction of Absorbed Photosynthetically Active Radiation (fAPAR) is the light energy available for plant productivity and can be determined by ground and satellite methods. **Nelson et al. (2017)** compared three fAPAR satellite products (GEOV1, MODIS C5, and MODIS C6) with the aim to validate them against ground references (Apogee PAR sensors, PASTIS-PAR sensors, and digital hemispherical photographs (DHPs)) in a deciduous beech forest site in a gently and variably sloped mountain site in Italy. A good consistency among the three ground devices was found. The three satellite products showed good results over the peak season but they differ in their performance depending on the time of season and landscape. They all met the requirements on accuracy of the Global Climate Observing System (GCOS) in more than 85% of the cases for the MODIS products, and up to 98% of the samples for GEOV1.

Approaches in ecological methodology and modelling

ICP Forests data also contributed to several studies on methodological and modelling approaches regarding various research areas.

The modelling of ozone fluxes is very restricted due to the model recommendation of hourly input data of ozone concentrations and meteorological variables. Ozone concentrations of high temporal resolution can be only measured by active samplers, but most monitoring sites feature passive samplers. To overcome these restrictions, **Calatayud et al. (2016)** tested five approaches of available input data. They concluded that with strict quality assurance of passive samplers it would be possible to calculate reasonable POD0 values with acceptable errors, however, the calculation of exceedances of O_3 flux-based critical levels by PODY metrics with a threshold is limited. This result will allow a wider use of ozone flux modelling at sites with passive samplers.

Modelling is also a useful method to study forest growth and the phenomena of masting. Using new data and new research findings, existing models are updated, improved or upgraded for novel outputs. **Guillemot et al. (2016)** implemented a new C allocation scheme into the process-based forest growth model CASTANEA to test how the environmental dependencies of the C allocation to leaves and wood affect the prediction of forest growth. For calibration and validation of the model, they used biometric measurements from the French Level I and Level II plots. The new implementation increased the intersite and inter-annual variability of aboveground forest growth along regional gradients. In addition, a significant effect of the previous year's water stress on the within-tree C allocation was shown. On the other hand, **Venner et al. (2016)** revisited the approach of resource budget models (RBM) to study how masting could be affected by the degree of pollination efficiency. For this, they replaced the current power functions by logistic functions coupling pollination success to pollen availability to model the outcross pollination. Using flowering and fruiting observations of 130 sessile oak trees in France, they separated the RBM depletion coefficient into explicit biological parameters. Their new model showed that masting should be most intense when pollination is low-effective.

Ewald and Ziche (2017) verified the widely used Ellenberg nutrient values with chemistry proxies of soil nutrient availability, finding that in German Forest soils the Ellenberg nutrient value related consistently to measurable chemical proxies, but best to the C/N ratio of the topsoil. They propose that a five-class trophic scale can be used to compare the Ellenberg nutrient values between studies.

Since soil water retention or hydraulic conductivity functions generally only consider fine-earth conditions, **Wegehenkel et al. (2017)** tested how stoniness correction affected a numerical water balance modelling approach. The evaluation with daily throughfall, soil water contents and pressure heads measured at three German ICP Forests Level II plots showed an increased model performance, emphasizing the need for stoniness correction.

In addition to these studies using Level II data as drivers or responses, the ICP Forests network provides background information for a variety of projects. For example, **Nickel and Schröder (2017)** used monitoring data in an effort to spatially optimize the German moss monitoring network. Further, **Fleck et al. (2016)** compiled and aggregated the current status of the ICP Forests Level II soil database combining physicochemical and hydraulic variables, thereby providing a wide range of parameters as checked background information and consolidated starting point for new analyses.

List of ICP Forests scientific publications (06/2016–05/2017)

Agnan Y, Probst A, Séjalon-Delmas N (2017) **Evaluation of lichen species resistance to atmospheric metal pollution by coupling diversity and bioaccumulation approaches: A new bioindication scale for French forested areas.** Ecol Indic 72:99–110. DOI: 10.1016/j.ecolind.2016.08.006

Bezlova D, Borissova Boneva M, Yankova-Tsvetkova E, Vassilev K (2016) **Survey of the concentration of heavy metals in beech leaves in the region of Central Balkan National Park, Bulgaria.** Phytologia Balcanica; International Journal of Balkan Flora and Vegetation 22(3):335–339

Calatayud V, Diéguez JJ, Sicard P, Schaub M, De Marco A (2016) **Testing approaches for calculating stomatal ozone fluxes from passive samplers**. Sci Total Environ 572:56–67. DOI: 10.1016/j.scitotenv.2016.07.155

Camino-Serrano M, Graf Pannatier E, Vicca S, Luyssaert S, Jonard M, Ciais P, Guenet B, Gielen B, Peñuelas J, Sardans J, Waldner P, Etzold S, Cecchini G, Clarke N, Galić Z, Gandois L, Hansen K, Johnson J, Klinck U, Lachmanová Z, Lindroos A J, Meesenburg H, Nieminen T M, Sanders TGM, Sawicka K, Seidling W, Thimonier A, Vanguelova E, Verstraeten A, Vesterdal L, Janssens IA (2016) **Trends in soil solution dissolved organic carbon (DOC) concentrations across European forests.** Biogeosciences 13:5567–5585. DOI: 10.5194/bg-13-5567-2016

Cervellini M, Fiorini S, Cavicchi A, Campetella G, Simonetti E, Chelli S, Canullo R, Gimona A (2017) **Relationships between understory species specialists and local management practices in coppiced forests – Evidence from the Italian Apennines.** For Ecol Manag 385:35–45. DOI: 10.1016/j.foreco.2016.11.027

Delpierre N, Guillemot J, Dufrêne E, Cecchini S, Nicolas M (2017) **Tree phenological ranks repeat from year to year and correlate with growth in temperate deciduous forests**. Agr Forest Meteorol 234–235:1–10. DOI: 10.1016/j.agrformet.2016.12.008

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3 SUMMARY OF THE 5TH ICP FORESTS SCIENTIFIC CONFERENCE, LUXEMBOURG, 10-12 MAY 2016

The 5th ICP Forests Scientific Conference *Tracing air pollution and climate change effects: trend and risk assessments* was hosted by the Luxembourg Administration de la nature et des forêts and held at the Ministry of Sustainable Development and Infrastructure - Department of the Environment in Luxembourg on May 10–12, 2016 with 77 participants from 29 countries.

The conference was aimed at scientists in the field of air pollution and climate change research in forests and specifically scientists and experts from ICP Forests, the UNECE ICP community under the Working Group on Effects (WGE), partners and stakeholders, and interested scientists from related fields. Researchers engaged in projects, evaluations and modelling exercises based on ICP Forests data, or working in co-operation with ICP Forests were encouraged to present and discuss their work and results.

The conference concentrated on evaluations and methods with respect to both environmental drivers (such as N deposition, ozone, climate) and forest responses (like tree health and growth, nutrient contents, diversity and mycorrhizas). Issues like the sustainability of ecosystem services and forest management options are closely connected to environmental impacts and ecosystem responses and were also discussed.

The main topics of the conference were:

- Nitrogen in forest ecosystems including biodiversity issues
- The role of sulphur and basic cations in forest ecosystems
- The impact of ozone
- Heavy metals in forests — still a challenge?
- Climate change effects on forests and water budget issues

The 5th Scientific Conference of ICP Forests particularly focussed on the value of long-term data in forest ecosystem research as the impact of air pollutants on forest ecosystems and their interaction with climate fluctuation and change, pests, or disease can best be evaluated by means of long-term data, allowing trends and risk analyses.

The following list includes all presentations and posters given at the 5th ICP Forests Scientific Conference. All conference abstracts are available from the ICP Forests website[1].

Augustin N, Griffiths A, Lindgren F, Eickenscheidt N, Wellbrock N [Presentation] **Improved trend estimation of European spatio-temporal forest health monitoring data**

Bičárová S, Pavlendová H, Sitková Z, Pavlenda P [Presentation] **Model estimation of POD1 and growing season length**

Canullo R, Giorgini D, Campetella G, Zouglami K [Presentation] **Spatial and temporal patterns of plant diversity in the Italian forest monitoring network (CONECOFOR)**

Clarke N, Lachmanová Z, Matucha M [Presentation] **Modelling climate change effects on the chlorine cycle in a Norway spruce forest soil**

Cools N, De Vos B, Verstraeten A, Roskams P [Presentation] **Do changes in forest soil properties reflect the decrease of acidifying deposition in Flanders?**

Daenner M, Raspe S, Waldner P [Presentation] **Generating of gapless meteorological data for water budget modelling of Level II plots**

Galić Z, Orlović S, Novčić Z [Poster] **Trends of soil moisture content in Hungarian oak stands**

Gottardini E, Calatayud V, Ferretti M, Haeni M, Schaub M [Presentation] **Temporal and spatial distribution of ozone symptoms across Europe from 2002 to 2014**

Gottardini E, Cristofolini F, Cristofori A, Ferretti M [Presentation] **ViburNeT – The *Viburnum lantana* ozone biological response Network in Trentino, Italy**

Hůnová I, Kurfürst P, Stráník V [Presentation] **Nitrogen deposition to forest ecosystems with focus on its different forms**

Hurdebise Q, Bergmans B, Aubinet M [Presentation] **Ozone concentration extreme events identification and analysis in a temperate mixed forest**

Inclán RM and the GuMNet Consortium Team [Poster] **GuMNet - A high altitude monitoring network in the Sierra de Guadarrama (Madrid, Spain)**

Jeran Z, Mazej D, Skudnik M, Kastelec D [Poster] **Environmental factors and canopy drip effect on heavy metals in mosses collected in Slovenian forests**

Johnson J, Verstraeten A, Meesenburg H, Vesterdal L, Hansen K, Vanguelova E, Jonard M, Graf Pannatier E, Sintermann J, Nieminen TM, Carnicelli S, Cecchini G, Clarke N [Presentation] **Temporal trends in soil solution acidity indicators in European forests**

König N, Meesenburg H, Scheler B, Fortmann H, Wagner M, Klinck U, Gehrmann J [Presentation] **Long-term monitoring of heavy metal input, retention and output over the last 30 years – results from Lower Saxony, Hesse and North Rhine-Westphalia, Germany**

Markovic M, Rajkovic S, Rakonjac L [Poster] **Biofungicides in nursery production**

Merilä P, Tonteri T, Hallikainen V, Rautio P, Korpela L, Salemaa M [Presentation] **Light requirements direct the response of understory plants to forest cuttings**

Michopoulos P, Kostakis MG, Bourletsikas A, Kaoukis K, Karetsos G, Thomaidis NS, Passias IN [Poster] **Concentrations of Cd and Pb in bulk precipitation, throughfall, plant tissues and soil in a remote mountainous fir forest in Greece**

Neagu S, Hanzu M [Poster] **Merging effects of air pollution and climate change on forest growth in Romania**

Nickel S, Schröder W, Jenssen M [Poster] **Modelling and mapping soil moisture for observed and future periods. A Germany-wide and regionally specified fuzzy approach**

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[1] http://www.icp-forests.net/page/icp-forests-other-publications

Nieminen TM, Derome K, Lindroos A-J, Merilä P [Presentation] **Elevated sulfate and trace element concentrations in soil solution of an acid sulfate forest soil**

Percy KE [Presentation] **Forest health monitoring in the Alberta Oil Sands, Canada: Design, results and linkage to ICP Forests**

Popa I, Badea O, Leca S, Silaghi D [Poster] **Trend analysis of trees health status in the ICP Level I network in Romania. Synchronized with climate trend?**

Rajkovic S, Markovic M, Rakonjac L [Poster] **Monitoring Plot – CRNI VRH – Ozone injury**

Schröder W, Nickel S, Schütze G [Presentation] **German moss survey: Quality controlled collection of data on heavy metals, nitrogen and persistent organic pollutants**

Sicard P, Dalstein-Richier L [Poster] **Health and vitality assessment of two common pine species in the context of climate change in Southern Europe**

Sicard P, De Marco A, Dalstein-Richier L, Tagliaferro F, Paoletti E [Presentation] **An epidemiological assessment of stomatal ozone fluxbased critical levels for visible ozone injury in Southern European forests**

Sicard P, Rossello P [Poster] **Spatio-temporal trends of surface ozone concentrations and metrics in France**

Sintermann J, Waldner P, Graf Pannatier E [Poster] **Characterising long-term trends of soil solution acidification at Swiss ICP Forests sites**

Torres B, Manzano MJ, Prieto JM [Poster] **Using data from the European Large-scale forest condition monitoring (Level I) for the modeling of *Cerambyx* spp. suitable habitat under different climate change scenarios**

Ukonmaanaho L, Nieminen TM, Lindroos A-J, Nevalainen S, Lindgren M, Derome K, Rautio P, Merilä P [Presentation] **Litterfall, defoliation and inorganic nitrogen solute concentration before and after bark beetle outbreak in a Norway spruce forest**

Van der Linde S, Grebenc T, Hansen K, Meesenburg H, Merilä P, Vanguelova E, Verstraeten A, Bidartondo MI [Presentation] **The large-scale diversity, distribution and environmental drivers of Europe's forest ectomycorrhizas**

Vanguelova E, Benham S [Presentation] **Base cations and nitrogen budgets of forest ecosystems in the UK**

Verstraeten A, Neirynck J, Cools N, Roskams P, Sleutel S, De Neve S [Presentation] **Nitrogen status of Flemish forests is improving**

Verstraeten A, Verschelde P, De Vos B, Neirynck J, Cools N, Roskams P, Hens M, Louette G, Sleutel S, De Neve S [Poster] **Increasing dissolved organic nitrogen (DON) concentrations and fluxes in temperate forests underrecovery from acidification in Flanders, Belgium**

Weis W, Schmidt-Walter P, Von Wilpert K [Presentation] **Using soil inventory data to calculate linked output of nitrogen, sulphur and base cations in German for ests**

Zhiyanski M, Gikov A, Nedkov S, Dimitrov P, Naydenova L [Poster] **Assessing and mapping land cover related carbon stocks in the mountain treeline zone under global change during 1982-2012**

4 ONGOING ICP FORESTS PROJECTS

ICP Forests welcomes scientists from within and outside the ICP Forests community to use ICP Forests data for research purposes. Data applicants must fill out a data request form and send it to the Programme Co-ordinating Centre of ICP Forests thereby consenting to the ICP Forests Data Policy. For more information, please refer to the ICP Forests website[1].

The following list provides an overview of all the 49 ICP Forests projects that were ongoing for at least one month between June 2016 and May 2017. In this period, 17 new projects have started (s. ID number with *). All past and present ICP Forests data uses are listed on the ICP Forests website[2].

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
14	John Caspersen	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Global Forest Monitoring	External
25	Dr. Nicole Augustin	University of Bath	Spatial-temporal modelling of defoliation in European forests	External
30	Volker Mues	Institute for World Forestry	FORMIT, Grant Agreement No. 311970 under the 7th EU-Framework Programme "FORest management strategies to enhance the MITigation potential of European forests"	Internal
54	Dr. Elke Keup-Thiel, Dr. Juliane Otto	Climate Service Center 2.0	Calculation of climate changes impacts indicators for tree species distribution	External
55	Ivan Janssen	University of Antwerp	Effects of phosphorus limitations on Life, Earth system and Society (IMBALANCE-P)	External
61	Roberto Canullo	Università degli Studi di Camerino School of Biosciences and Veterinary Medicine	FUTPA: Plant functional trait patterns in key EU forest types	Internal
63	Jesus San-Miguel	European Commission - Joint Research Centre	Distribution maps of forest tree species	External
67	Dr. Stefan Fleck	Northwest German Forest Research Institute (NW-FVA)	LAI-estimations with allometry, litter collections, and optical measurements in relation to stand properties and microclimate	Internal
68	Shengwei Shi	College of Forestry, Northwest A & F University, China	Modeling dissolved organic carbon in forest soils using a TRIPLEX-DOC model	External
73	Christopher Reyer	Potsdam Institute for Climate Impact Research (PIK)	COST Action FP 1304 Towards robust projections of European forests under climate change (PROFOUND)	External

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[1] http://icp-forests.net

[2] http://icp-forests.net/page/project-list

[3] Internal Evaluations can be initialized by the Chairperson of ICP Forests, the Programme Co-ordinating Centre, the Expert Panel Chairs and/or other bodies under the LRTAP Convention. Different rights and obligations apply to internal vs. external data users.

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
75	Andres Bravo Oviedo	INIA-Forest Research Centre	ICP Forests-EuMIXFOR Interaction: Evaluation of soil and foliar nutrient status of mixed vs. pure stands in Europe as categorized by European Forest Types	External
76	Karin Hansen	IVL Swedish Environmental Research Institute	Atmospheric Deposition: EMEP - ICP Forests comparisons of level, trend and canopy exchange	Internal
78	Elisabeth Graf Pannatier	Swiss Federal Institute for Forest, Snow and Landscape Research	Temporal trends in soil solution acidity in European forests	Internal
79	Peter Waldner	Swiss Federal Institute for Forest, Snow and Landscape	Nitrate leaching risk mapping (NitLeach)	Internal
81	Robert Weigel	Ernst-Moritz-Arndt-University (Greifswald)	"The ecological and biogeochemical importance of snow cover for temperate forest ecosystems" and "Phenotypic plasticity and local adaptation in beech provenances (Fagus sylvatica)"	External
84	Yasmina Loozen	Utrecht University, Faculty of Geosciences	Taking a remote look at canopy nitrogen to improve global climate models	External
85	Sietse van der Linde	Imperial College London & Royal Botanic Garden, Kew	Large-scale diversity, distribution and fate of Europe's forest mycorrhizas	Internal
86	Josep Peñuelas, Jordi Sardans	CREAF - Global Ecology Unit	Plant-soil Stoichiometry relationships with tree growth and health along Environmental gradients	External
87	Valerio Avitabile	Wageningen University	GlobBiomass	External
88	Axel Göttlein	Technical University Munich	Specification of biogeochemical thresholds for the cultivation of important forest tree species in the face of climate change	External
89	Janusz Czerepko	Instytut Badawczy Leśnictwa	DWpool: Deadwood estimation through forest ecosystems in Europe	Internal
90	Mathias Neumann	University of Natural Resources and Life Sciences	FORMIT – Forest management strategies to enhance the mitigation potential of European forests	External
91	Peter Waldner	Swiss Federal Institute for Forest; Snow and Landscape (WSL)	Seed C 2 – Carbon allocation to fruits and seeds in European forests as a function of climate, atmospheric deposition and nutrient supply	Internal
92	Ece Aksoy	European Topic Center - Urban, Land, Soil (ETC_ULS) of European Environment Agency (EEA)	Land Resource Efficiency Task of European Environment Agency	External
93	Martina Temunović	University of Zagreb, Faculty of Forestry	Phenotypic and Genetic Diversity of Pedunculate oak (Quercus robur L.) in Europe – FGErobur	External
94	Hrvoje Marjanović	Croatian Forest Research Institute	Estimating and Forecasting Forest Ecosystem Productivity by Integrating Field Measurements, Remote Sensing and Modelling	External

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
95*	Gaia Vaglio Laurin	University of Tuscia	Very high resolution monitoring of EU forest ecosystems: understanding advancements now possible by means of new satellite remote sensing data	External
96	Myriam Legay	Office National des Forêts	IKSMaps: Providing precalculated future distribution maps for the main French forestry species through IKS model	External
97*	Stefan Neagu	National Research and Development Institute for Forestry (INCDS)	Carpathian forests' health status and risks	External
98*	Susanne Brandl	Bavarian State Institute of Forestry	Alterations in the lifetime of forest stands: Economic consequences of climate change for forestry enterprises. Management options for optimizing risk-return ratios under a changing climate	External
99	Andrea Cutini	CREA SEL Arezzo	Shaping future forestry for sustainable coppices in southern Europe: the legacy of past management trials (FutureForCoppiceS)	External
100*	Dr. Michael Kessler	Institute of Systematic and Evolutionary Botany, University of Zurich, Switzerland	Understanding global patterns of fern diversity and diversification	External
101*	Dr. Ulrich Matthes	Rhineland-Palatinate Centre of Excellende for Climate Change Impacts	Adapting forestry to climate change in Rhineland-Palatinate (Germany)	External
102*	Jean-Pierre Wigneron	ISPA, Institut National de La Recherche Agronomique (INRA), Bordeaux	Evaluating the use of passive microwave products (soil moisture and vegetation optical depth) to monitor drought impacts on forests	External
103*	Tanja Sanders	Programme Co-ordinating Centre of ICP Forests	Linking satellite derived land surface temperature (LST) to defoliation status of forests	Internal
104	J. Julio Camarero	Instituto Pirenaico de Ecología (IPE, CSIC)	Exploring whether functional diversity confer resistance and resilience to drought in forests	External
105	Bart Muys	KU Leuven	FORBIO Climate - Adaptation potential of biodiverse forests in the face of climate change	External
106*	Tanja Sanders	Programme Co-ordinating Centre of ICP Forests	Generic parameterization of a tree-growth model	Internal
107	Marcus Schaub	WSL	PRO3FILE - Predicting Ozone Fluxes, Impacts, and Critical Levels on European Forests	Internal
108*	Nicolas Delpierre	Université Paris-Sud	IMNIFOR (IMpact of NItrogen nutrition on the production of European FORests)	External
109*	Marco Keiluweit	University of Massachusetts - Amherst	Predicting the impact of redox constraints on soil carbon storage across ecosystem scales	External
111*	Lukas Baumbach	University of Freiburg	Species distribution modelling of European beech - silver fir mixed forests in the face of extreme climate events	External

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
112*	Anne-Katrin Prescher	Programme Co-ordinating Centre of ICP Forests	Change in Sulphur pools in forest ecosystems following the reduction of atmospheric SO2	Internal
113	Caroline Vincke	Université Catholique de Louvain-La-Neuve	Oak vulnerability in Wallonia region : impacts of growth conditions on stand's vitality and forestry options	External
114*	Jing Tang	University of Copenhagen	Diagnosis of processes controlling soil dissolved organic matter (DOM) concentration in diverse ecosystem, using dynamic ecosystem model, LPJ-GUESS	External
115*	Leho Tedersoo	University of Tartu	Differences in mycorrhizal types in determining soil properties and processes and microbial diversity in European forests	External
116*	Carmen Hernando	National Insitute for Agricultural and Food Research and Technology (INIA)	Fire severity reduction through new tools and technologies for integrated forest fire protection management (GEPRIF)	External
117*	Walter Seidling	Thünen Institute of Forest Ecosystems	ICP Forests and ICP Integrated Monitoring provide detailed information enabling analyses of environmental and ecosystem changes in time and aggregations in space	Internal
118*	Björn Reineking	Institut national de recherche en sciences et technologies pour l’environnement et l’agriculture (IRSTEA)	Resilience mechanisms for risk adapted forest management under climate change (REFORCE)	External

Part B

Reports on individual surveys in ICP Forests

5 SPATIAL VARIATION OF ATMOSPHERIC DEPOSITION IN EUROPE IN 2015

Andreas Schmitz, Peter Waldner, Arne Verstraeten, Karin Hansen[1]

Summary

Monitoring the atmospheric deposition to forests is a prerequisite for understanding forest ecosystem processes and an important contribution for evaluating the spatio-temporal trends of air pollution. In this report, we present the annual throughfall deposition of eutrophying, acidifying and buffering components on ICP Forests Level II plots in 2015.

The nitrogen (N) compounds nitrate (NO_3^-) and ammonium (NH_4^+) are the main drivers of eutrophication and also contribute to acidification. High deposition rates to forests (throughfall deposition > 8 kg N ha^{-1} yr^{-1}) were measured at several plots in central Europe (Belgium, Germany) but also in the Czech Rupublic, Denmark and southern Sweden. Low depositions rates have been reported primarily in northern Europe.

Sulfate (SO_4^{2-}) has been the most important driver of soil acidification. High deposition of SO_4^{2-} (throughfall deposition > 8 kg SO_4^{2-}-S ha^{-1} yr^{-1}) was still found in central Europe (e.g. Belgium, Germany) as well as in the Czech Republic. In addition, high sulfate deposition occurred in southern Europe (Italy, Greece) which is probably related to natural sources.

Similarly, high calcium (Ca^{2+}) deposition across southern Europe is likely related to contributions from Saharan Dust. The spatial pattern of magnesium (Mg^{2+}) deposition is mainly dominated by marine sources. Both $Ca^{2+}$and Mg^{2+} are macronutrients and act as buffers against acidification.

The overall spatial patterns of deposition of eutrophying, acidifying and buffering substances in 2015 remained similar to results from the previous years.

5.1 Introduction

For several substances, atmospheric deposition is one of the main sources of input to forests and the past or current magnitude of the deposition has been sufficient to trigger changes in forest ecosystems. Elevated sulfate (SO_4^{2-}) and inorganic nitrogen inputs are for example known to accelerate forest soil acidification (Bobbink and Hettelingh 2011). This change of chemical properties may induce further changes, for example affect the concentrations of dissolved organic carbon (DOC) (Sawicka et al. 2017). Deposition of base cations like calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) on the other hand can buffer the effects of acidifying components. As a success of clean-air-policy and economic transformation, emission and deposition of sulfur compounds in the countries participating in ICP Forests markedly decreased in the last decades (Waldner et al. 2014; EEA 2016). In addition to its acidifying effect, nitrogen serves as a nutrient for trees and understory vegetation (eutrophying effect). The raised availability of nitrogen due to anthropogenic emissions affects tree growth (Solberg et al. 2009; Magnani et al. 2007; Tamm 1991; Silva et al. 2015), carbon uptake by trees (Nair et al. 2016) as well as ground vegetation composition (Van Dobben and De Vries 2017; Rizzetto et al. 2016), mycorrhiza (Suz et al. 2014), and epiphytic lichens (Giordani et al. 2014). Nitrogen is mainly deposited as nitrate (NO_3^-) and ammonium (NH_4^+). Anthropogenic NO_3^- originates mainly from combustion processes like

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[1] For contact information, please refer to the annex.

road traffic, heating, the energy sector and industry. NH_4^+ on the other hand mainly originates from agricultural practices such as animal husbandry and fertilizer application. Both substances show decreasing trends in emission and deposition, though not as pronounced as for SO_4^{2-} (Waldner et al. 2014; EEA 2016).

An important component of deposition to forests is wet deposition by rain and snow. However, the forest canopy also filters particulate matter and gaseous substances from the air on wet surfaces (foliage, bark, wet snow) or inside stomata (dry deposition) as well as fog droplets and atmospheric humidity (occult deposition) (Mayer and Ulrich 1977; Ulrich et al. 1983). The dry deposited components are partly washed down from the canopy to the forest floor during rain events.

In order to assess the deposition to forests, bulk samplers (Figure 5-1) are positioned below the canopy (throughfall collectors) on ICP Forests intensive monitoring (Level II) plots. Especially for nitrogen, canopy exchange processes (uptake and leaching) complicate the interpretation of deposition rates. The total deposition of nitrogen can be up to a factor of two larger than those measured by throughfall collectors due to nitrogen uptake (Clarke et al. 2010). In addition to throughfall collectors, samplers are installed at nearby open-field sites to measure bulk deposition. Bulk deposition provides an estimate of the wet deposition, i.e. without the filtering effect of the forest canopy. Several canopy budget models have been developed to estimate the total deposition from bulk and throughfall deposition based on assumptions about canopy exchange processes (Annex Deposition Manual by Clarke et al. 2010, Adriaenssens et al. 2013). In this report, we focus on the annual throughfall deposition for 2015 for nitrate, ammonium, sulfate, calcium and magnesium.

Figure 5-1: Throughfall deposition sampler on a Level II plot in Switzerland close to Geneva (Image: Peter Waldner, WSL)

5.2 Materials and methods

Methods of bulk and throughfall sampling as well as chemical analysis are harmonized across participating countries within ICP Forests and follow the ICP Forests Manual (Clarke et al. 2010).

Quality control and assurance include laboratory ring-tests, use of reference material as well as conductivity and ion balance checks (König et al. 2010). In order to exclude implausible results of chemical analyses, the conductivity check (König et al. 2010) was repeated for each sampling period. If the unavailability of relevant ion concentrations (data gaps) did not allow calculating its contribution to conductivity, the samples were still considered plausible (check passed) if the incompletely calculated conductivity fell below the measured conductivity. The annual deposition was calculated for each substance as the product of the volume-weighted average concentration and the annual amount of precipitation. Plots were excluded if the conductivity check passed for less than 30% of the time of the year. In addition, the annual deposition was not used if the duration of sampling on a plot covered less than 90% (329 days) of the year. SO_4^{2-}, Ca^{2+} and Mg^{2+} originate to a certain extent from marine aerosols (sea salt). In order to assess the non-marine fractions of the deposition for these substances, sea-salt corrections were applied according to the ICP Modelling & Mapping (CLRTAP 2004), using chloride as tracer substance. Data from Sweden is kindly provided by the Swedish Throughfall Monitoring Network (SWETHRO). SWETHRO data collection follows the ICP Forests manual.

5.3 Results

Local and regional differences in precipitation amount, tree species and local sources (especially for NH_4^+) cause a high spatial variability of the throughfall deposition. On a larger scale, however, high atmospheric deposition of nitrogen compounds (NO_3^- and NH_4^+) occurs primarily in central Europe (Belgium, Germany, Czech Republic) but also in Denmark and southern Sweden; Figures 5-2, 5-3). Areas of low deposition (<1 kg N ha^{-1} yr^{-1}) are found in northern Europe and, for example, in rural parts of France.

High deposition of SO_4^{2-} is today restricted to areas in central Europe (e.g. Belgium, Germany) as well as to the Czech Republic but also Greece and Italy have higher deposition than other areas (Figure 5-4). In southern Europe, SO_4^{2-} deposition can be partly ascribed to volcanic activity and Saharan dust (Loÿe-Pilot, Martin, and Morelli 1986). The effect of sea-salt deposition is visible for a number of sites located close to the shore (e.g. in southern Sweden; Figure 5-5).

The difference between uncorrected and sea-salt corrected deposition is most pronounced for magnesium (Mg^{2+}), as this element is mainly related to marine aerosols with few local sources affecting concentrations at greater distance to the coast (Figures 5-6, 5-7).

For calcium (Ca^{2+}), Saharan dust is most likely responsible for high deposition across southern Europe (Rogora, Mosello, and Marchetto 2004) (Figures 5-8, 5-9). In addition, local mineral sources may result in episodes of high deposition at individual sites.

The overall spatial patterns of deposition for eutrophying, acidifying and buffering substances in 2015 remained similar to results from the previous years.

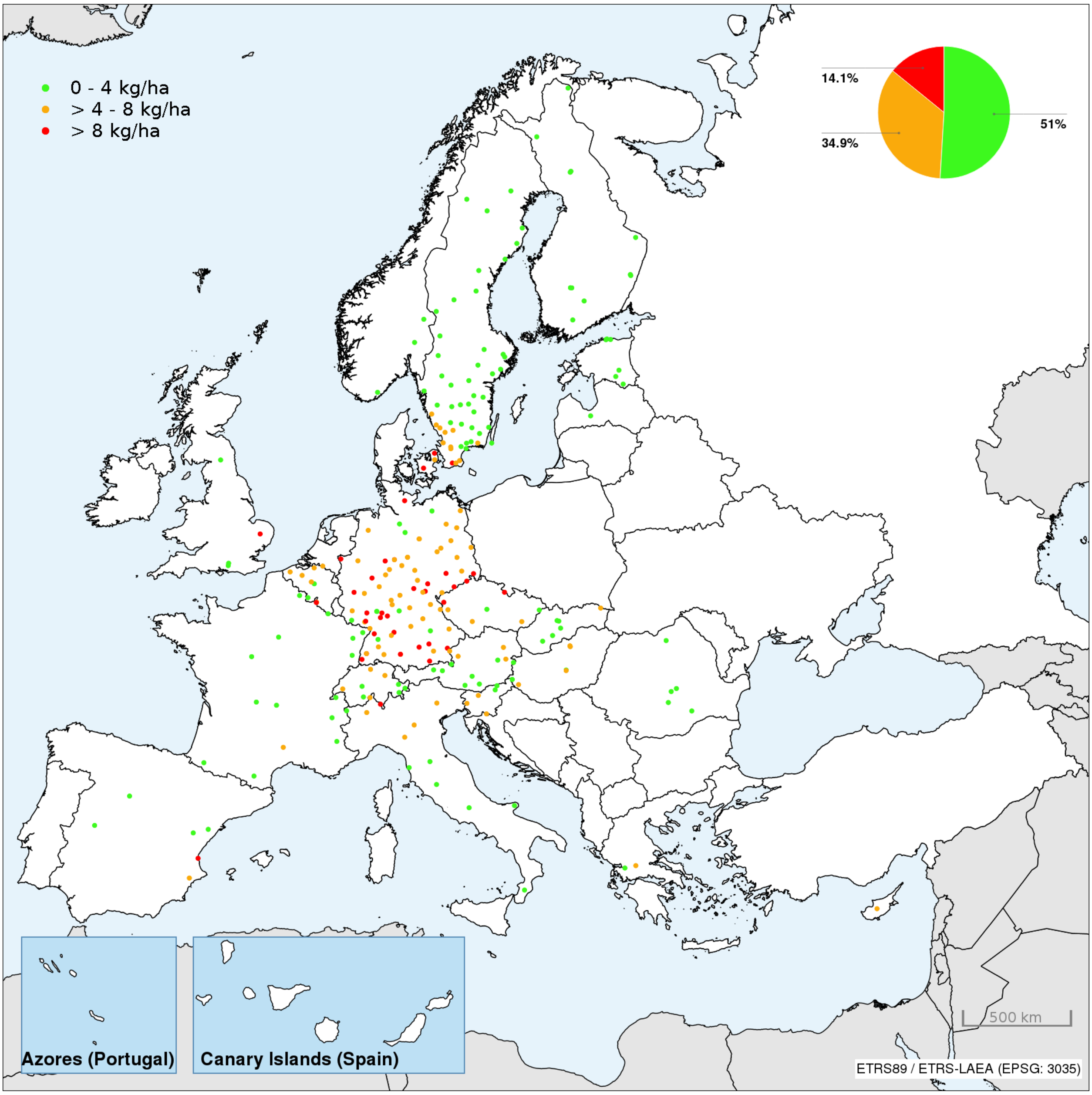

Figure 5-2: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

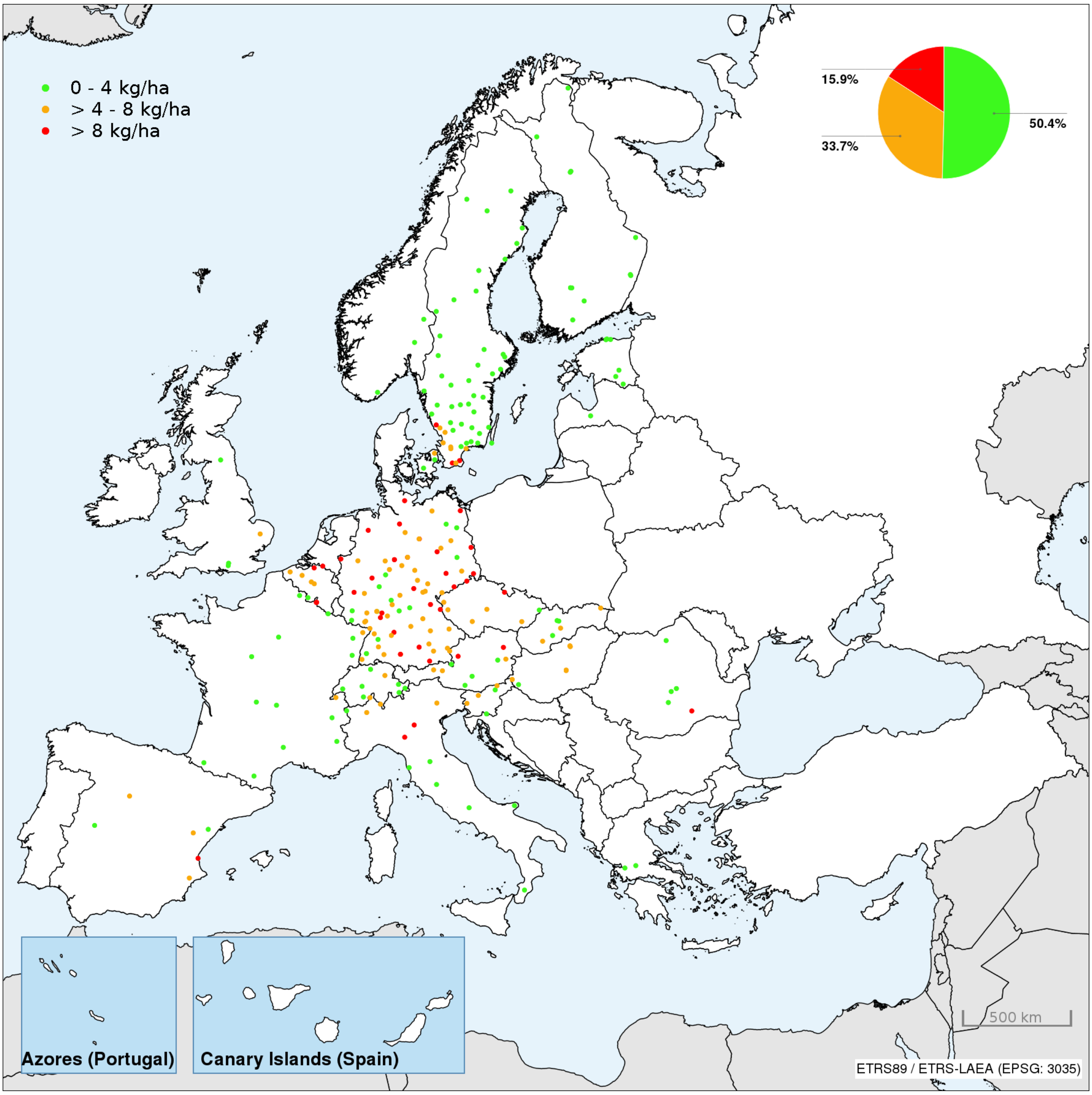

Figure 5-3: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

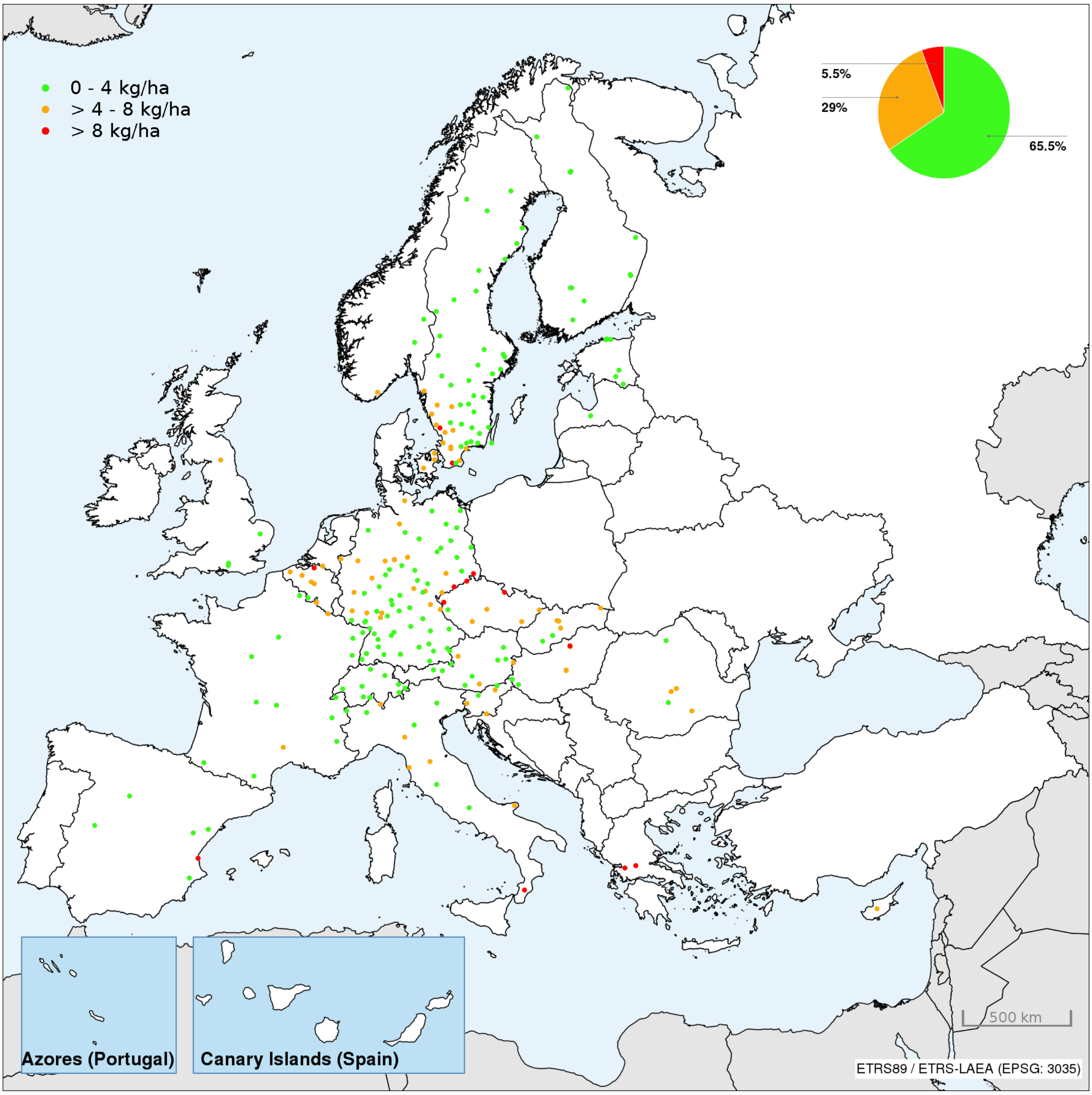

Figure 5-4: Throughfall deposition of sulfate-sulfur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

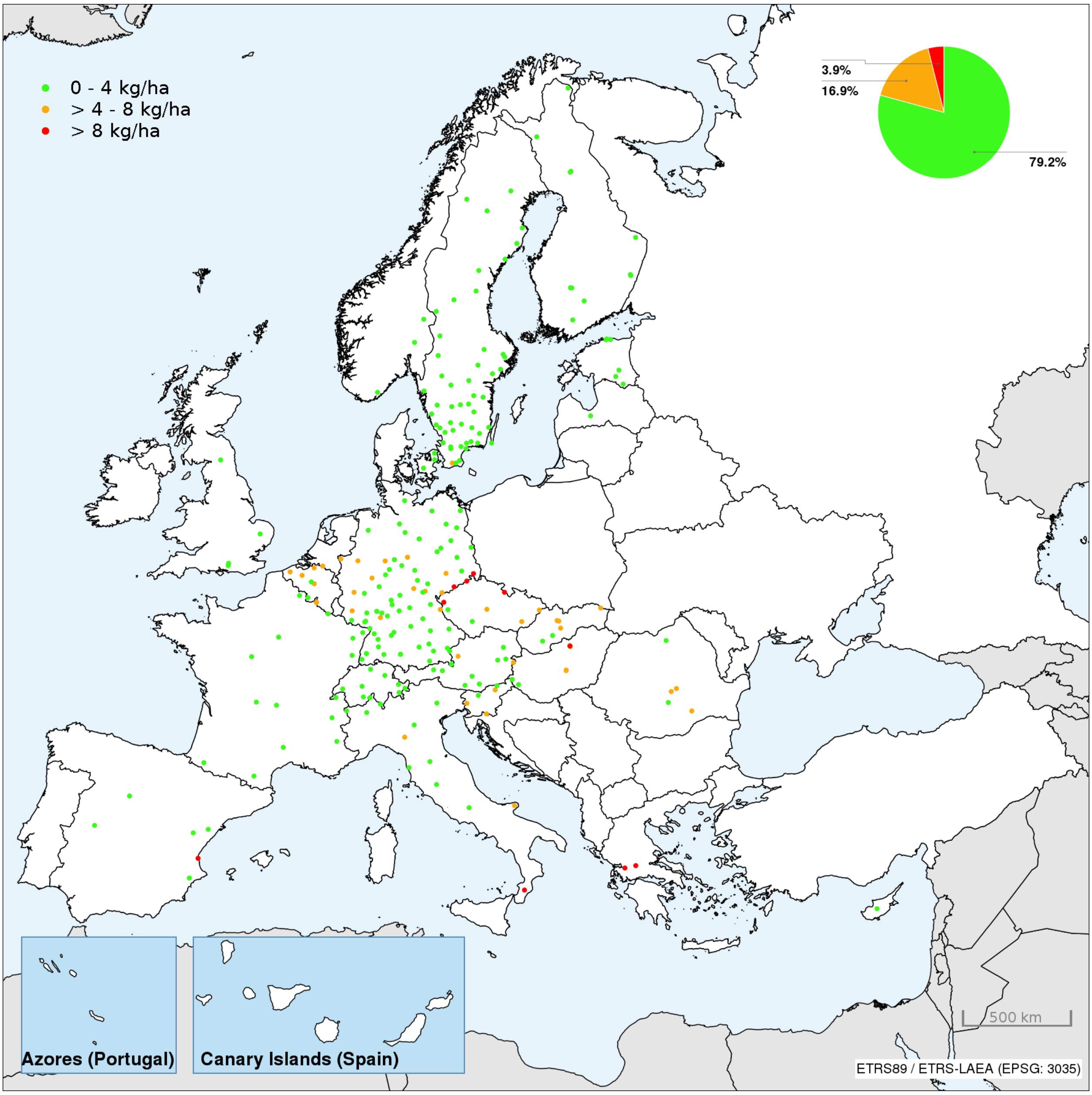

Figure 5-5: Throughfall deposition of sea-salt corrected sulfate-sulfur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

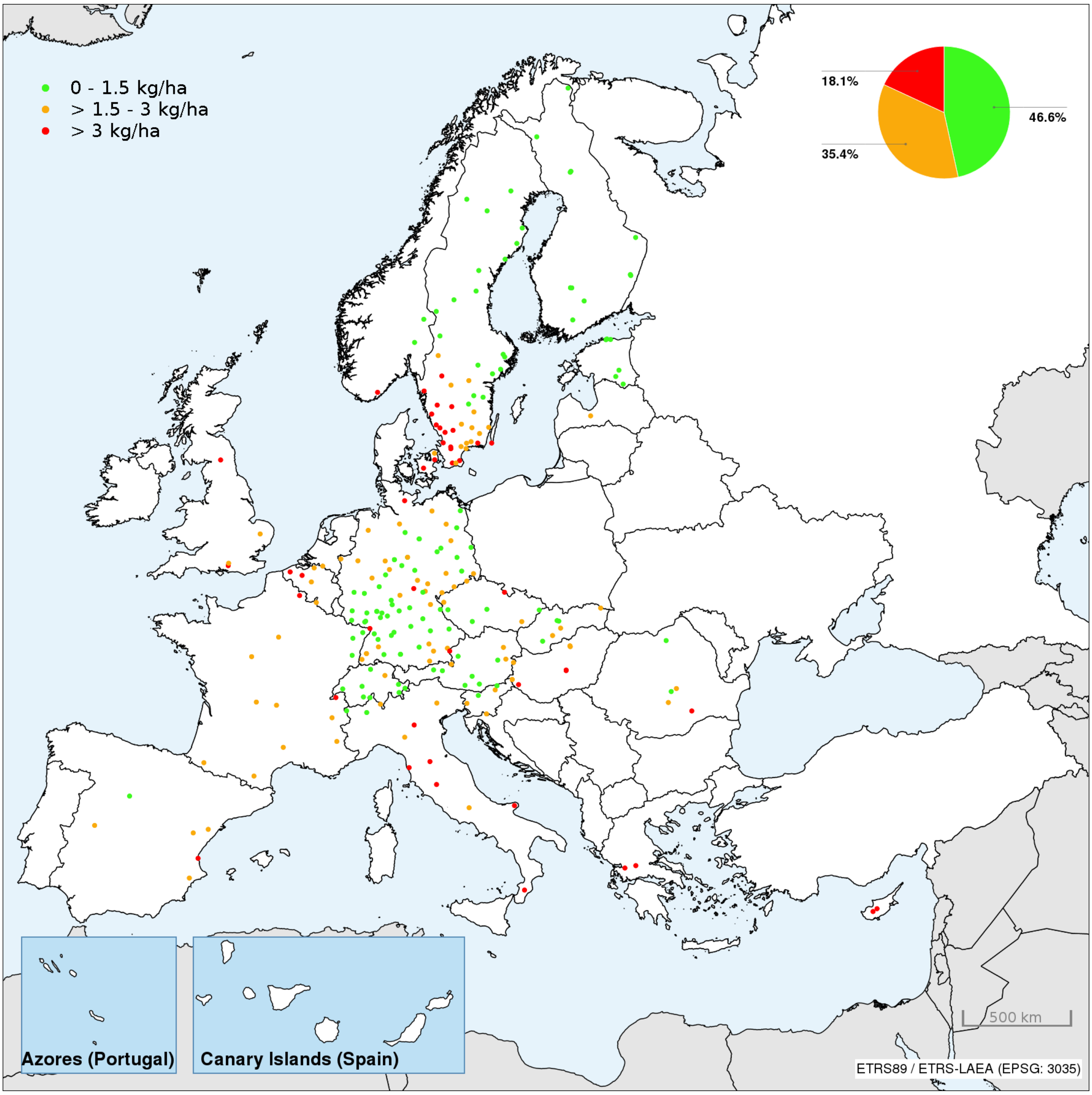

Figure 5-6: Throughfall deposition of magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

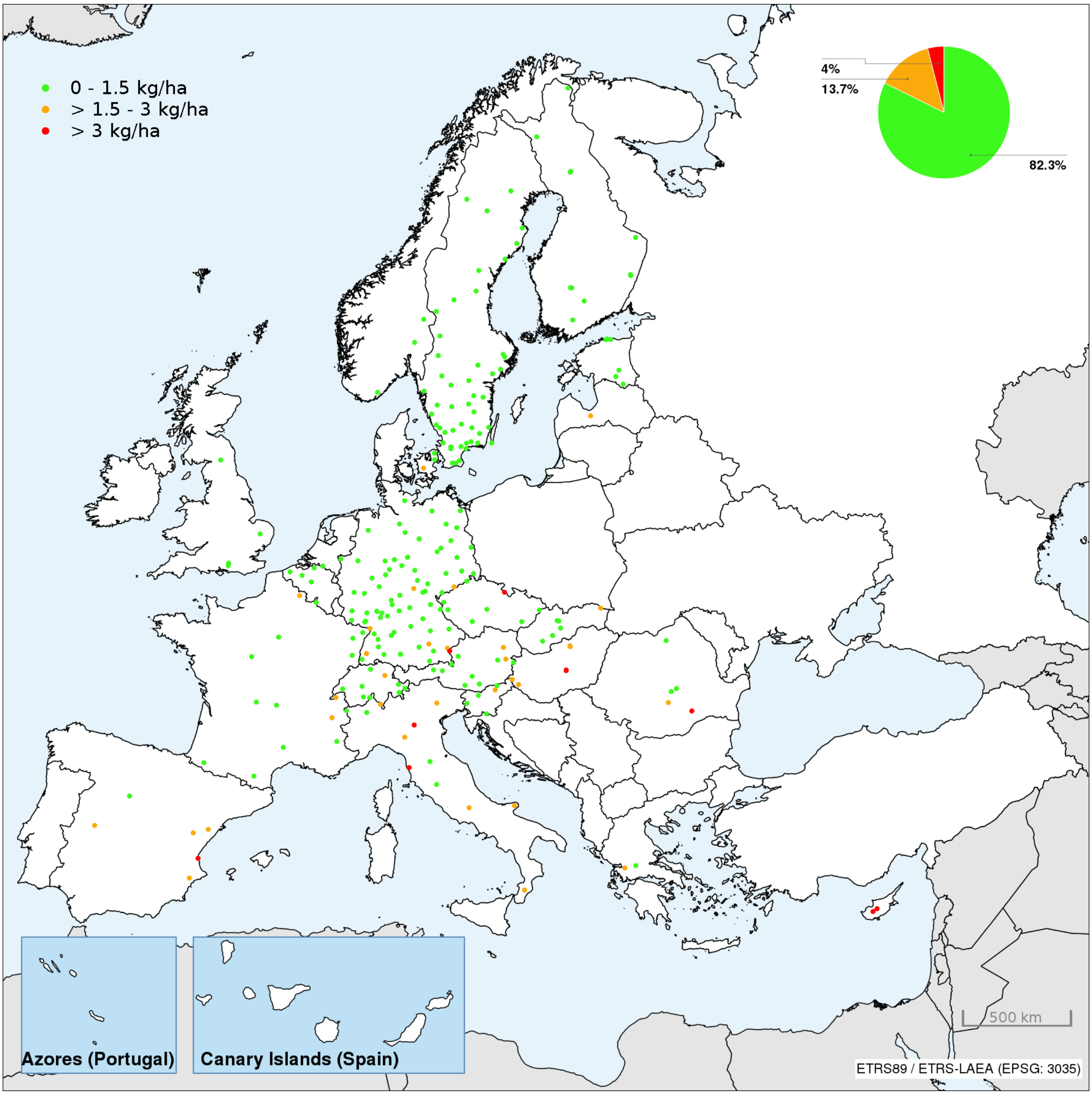

Figure 5-7: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

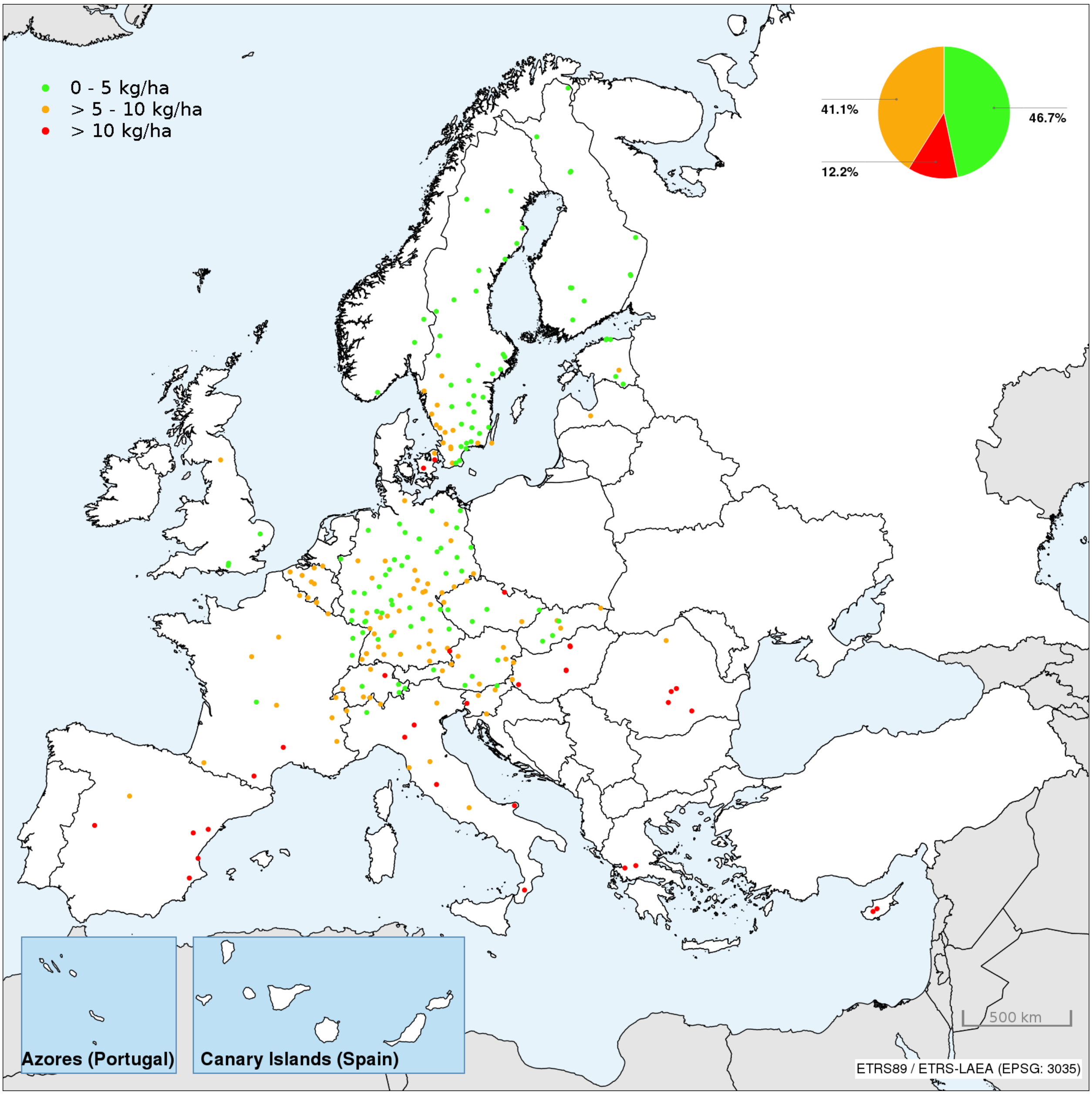

Figure 5-8: Throughfall deposition of calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

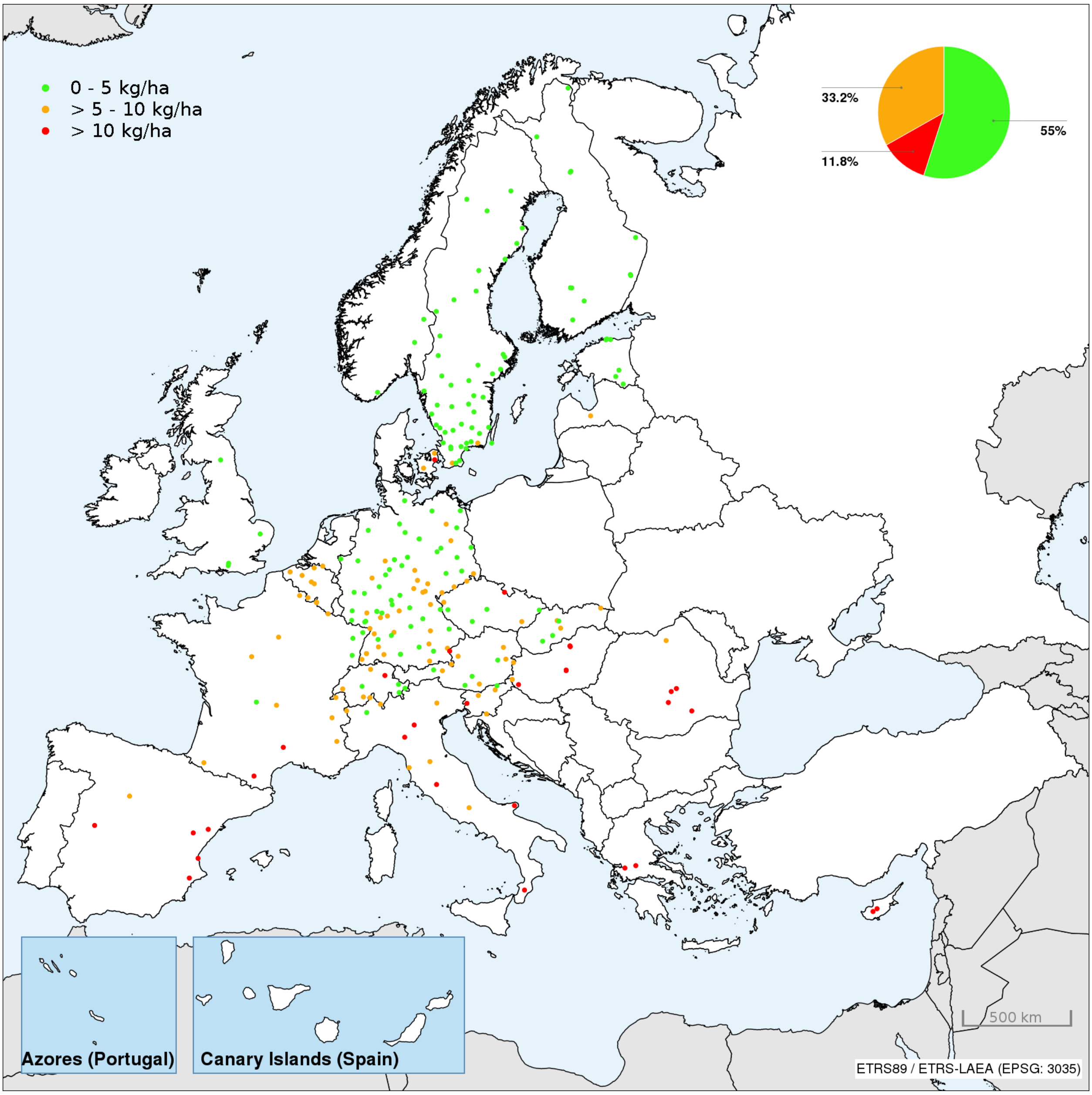

Figure 5-9: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2015 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network

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6 TRENDS IN FOLIAR NITROGEN AND PHOSPHORUS CONCENTRATIONS AND RATIOS SINCE 2000

Tanja GM Sanders, A Schmitz, Jens Edinger [1]

6.1 Introduction

Analyses of the chemical composition of leaves and needles over time and space allow the identification of trends and spatial patterns of the nutritional state of single trees and forest stands. At the specific monitoring site, nutrient limitations and surpluses can be detected as well as the impact of air pollutants which affect the chemical and physical condition of forest plots and therefore their nutritional state. These effects are reflected in changes of the nutrient concentrations in tree foliage and the corresponding nutrient concentration ratios. Other factors such as the productivity of foliar mass (Goswami 2015), soil acidity and tree age additionally influence nutrient concentrations depending on the species.

Jonard et al. (2015) analysed the development of tree mineral nutrition based on Level II foliage data between 1992 and 2009 for main tree species. They detected 22 significant nutrient concentration trends of which 20 were decreasing. Especially noticeable was the reduction of foliage phosphorus (P) in *Fagus sylvatica*, *Quercus petraea,* and *Pinus sylvestris.* This was confirmed by Talkner et al. (2015) who found continually decreasing foliar P concentrations in leaves of *Fagus sylvatica* in Europe between 1991 and 2010.

A variety of processes can be involved in causing decreasing trends in foliar P concentrations. They include (1) an increase in foliar mass ("dilution effect") (Jonard et al. 2015), (2) changes in growth rates, for example induced by N deposition or climate change (Norby et al. 2005), (3) high nitrogen (N) levels in the soils leading to a hindered P uptake (Jansa et al. 2011) or (4) slower soil organic matter decomposition could slow down nutrient cycling and reduce P availability (Peñuelas et al. 2013). All this may result in an unbalanced N:P ratio which is attributed to decreased tree vitality (Veresoglou et al. 2014).

This chapter reports on trends in foliar N and P concentrations and ratios in European beech (*Fagus sylvatica*), Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) trees on selected ICP Forests Level II plots since 2000.

6.2 Material and Methods

On the ICP Forests Intensive Forest Monitoring plots (Level II), foliar analyses are conducted at least biannually. For the main tree species of each plot, the foliage of at least five trees is sampled and analyzed for their element concentrations according to the ICP Forests Manual (Rautio et al. 2010).

Here we analyzed data from 181 plots on which the main species were European beech (*Fagus sylvatica*), Norway spruce (*Picea abies*), or Scots pine (*Pinus sylvestris*).Plots were included in the analyses if they had been sampled at least twice in both periods 2000–2005 and 2010–2015.

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[1] For contact information, please refer to the annex.

Furthermore, measurements on both nitrogen and phosphorus had to be present and within the plausibility ranges according to the ICP Forests Manual (Rautio et al. 2010, Annex II). Additionally, two plots were excluded showing implausibly high N:P ratios of over 85 for the second period (2010–2015). For *Picea abies* and *Pinus sylvestris* only current year needles were included in the analysis.

Critical ranges for foliar element ratios were taken from Mellert and Göttlein (2012) and modified for the "extreme deficiency" ranges to be below the "deficiency" range[1]. According to Mellert and Göttlein (2012), N:P ratios that range between 6.3–11.7 for *Pinus sylvestris,* between 7.4 and 14.1 for *Picea abies*, and between 10 and 18.9 for *Fagus sylvatica* are classed as normal.

Both, the levels and trends of foliar N and P concentrations and the N:P ratio were analyzed. For the levels, the average concentrations a decade ago (2000–2005) are compared with recent values (average 2010–2015). Trends were calculated according to linear regression with SAS and R and analysed over the complete assessment period from 1993 to 2015.

6.3 Results and Discussion

European beech (*Fagus sylvatica*)

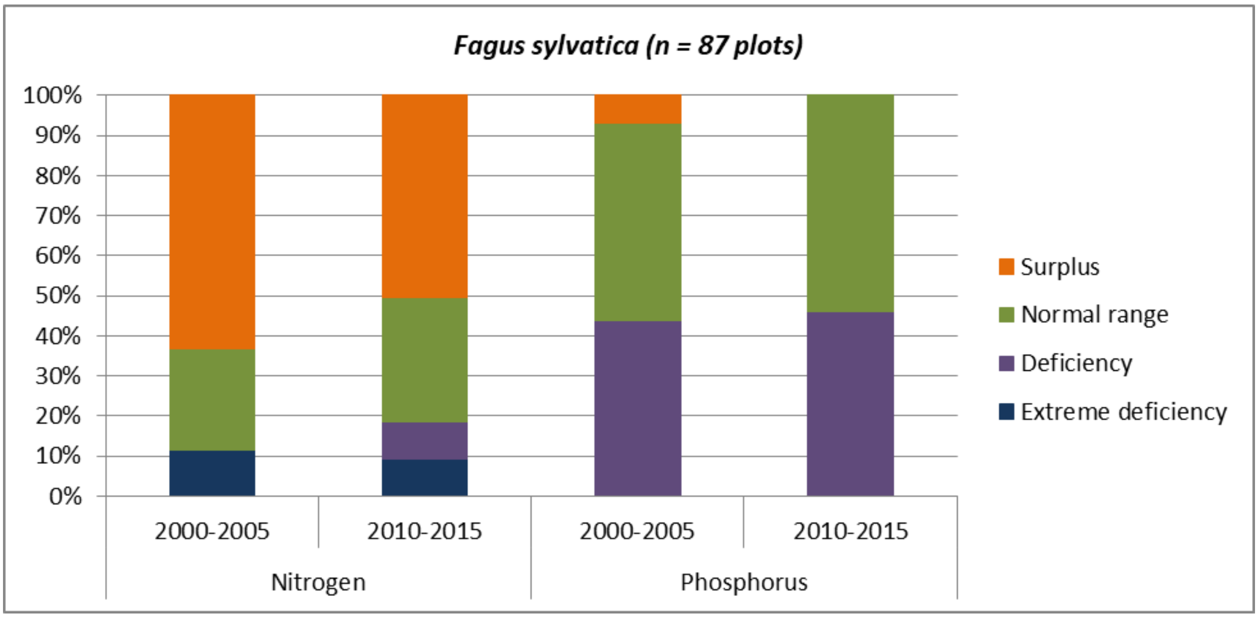

Figure 6-1: Comparison of foliar nitrogen and phosphorus concentration of European beech (*F. sylvatica*) between the periods 2000–2005 and 2010–2015, respectively

With 87 plots, *Fagus sylvatica* had the largest number of plots with at least two measurements present in both periods (Figure 6-1). The comparison of the nitrogen concentration in foliage between the two time periods shows a decreasing number of plots with a surplus of nitrogen (55 to 44 plots, i.e. 63% to 51%). At the same time the number of plots within the normal range increased slightly from 22 to 27 (25% to 31%) and the number of plots within the extreme deficiency range went down from ten to eight (11% to 9%). However, there are an additional eight plots (9%) within the deficiency range.

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[1] Here an obvious error occurred in the article;

Plots with a surplus of foliar phosphorus were reduced from six (7% of plots) to none between the two time periods. The number of plots within the normal range increased from 43 to 47 (49% to 54%) in the normal range and from 38 to 40 (44% to 46%) in the deficiency range.

These results are also reflected in the trends for the same set of 87 plots over the complete assessment period from 1993 to 2016 (Figures 6-2, 6-3) with a mean decrease in foliar nitrogen from 24mg/g to 22mg/g) and a mean decrease of foliar phosphorus from 1.4mg/g to 1.2mg/g). Thus causing an increase in the N:P ratio from 17.9 to 19.4.

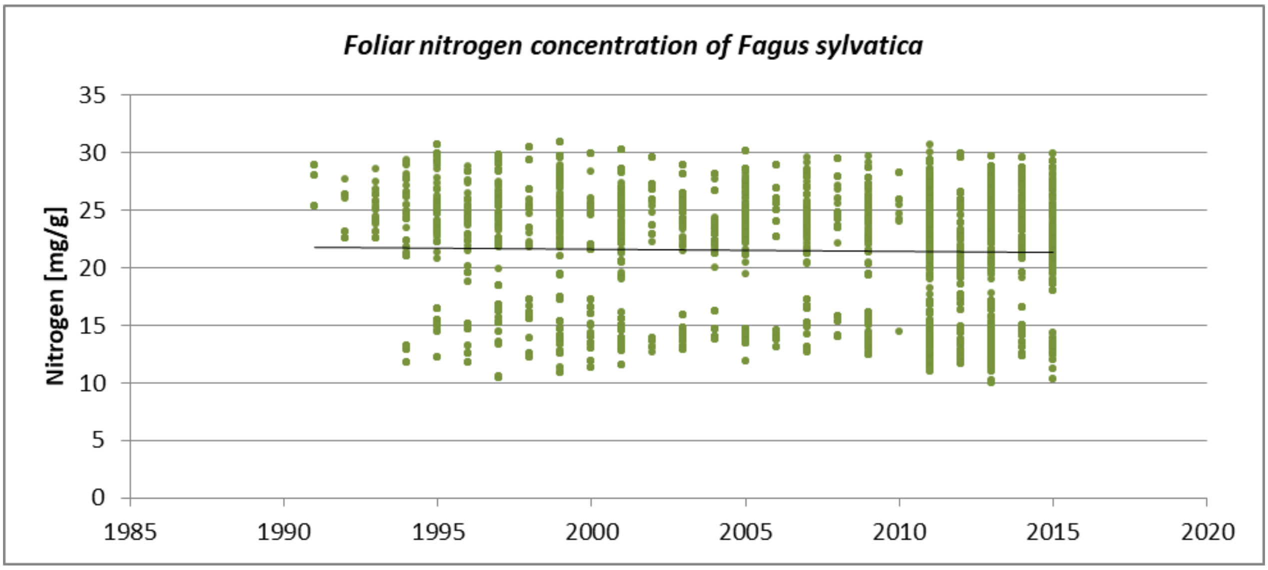


Figure 6-2: Trends in foliar N concentration (mg/g) in *Fagus sylvatica*. The “gap” can be seen within the data from Germany, Slovakia, Slovenia and Switzerland. The other countries included in the analysis tend to have foliar N concentrations well above or below 18 mg/g.

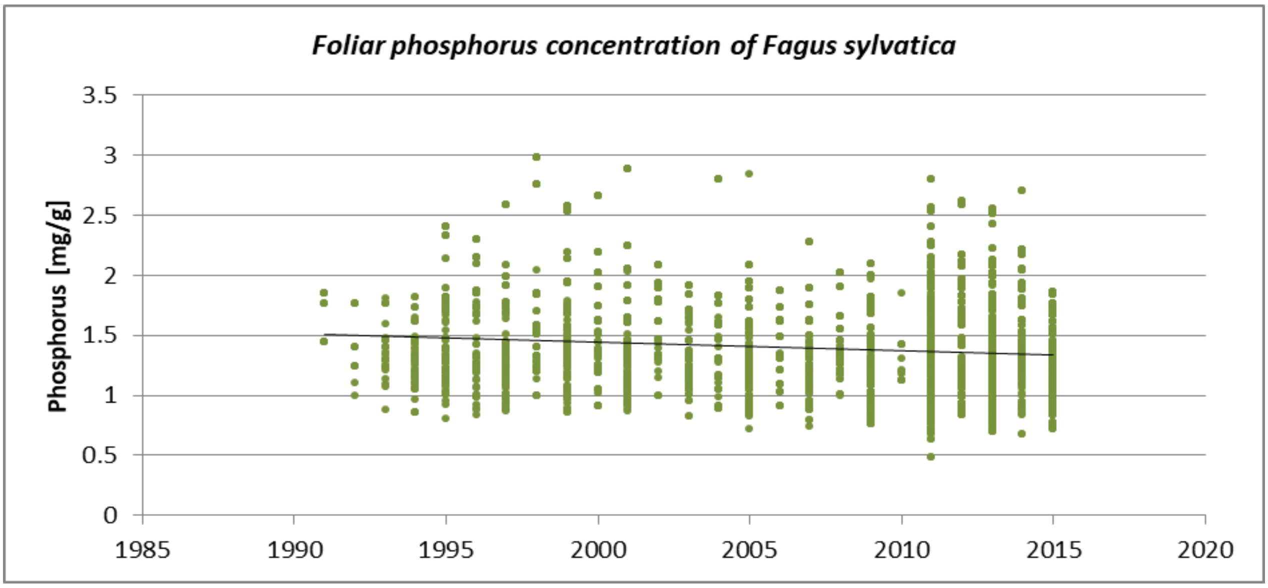


Figure 6-3: Trends in foliar P concentration (mg/g) in *Fagus sylvatica*

Norway spruce (*Picea abies*)

Picea abies made up the second largest set of plots in the analysis (59 plots). For foliar nitrogen concentrations, the number of plots in the surplus range increased from none to three (0% to 5%) between the two periods 2000–2005 and 2010–2015 (Figure 6-4). The number of plots within the normal range also increased by two, from 13 to 15 (22% to 25%). At the same time the number of plots within the deficiency range, however, decreased from 46 to 39 (78% to 66%) and three plots (5%) are now within the extreme deficiency range.

For foliar phosphorus the number of plots within the normal range decreased from 18 to 13 (31% to 22%) while the number in the deficiency range increased from 38 to 41 (64% to 69%) and in the extreme deficiency from three to five (5% to 8%).

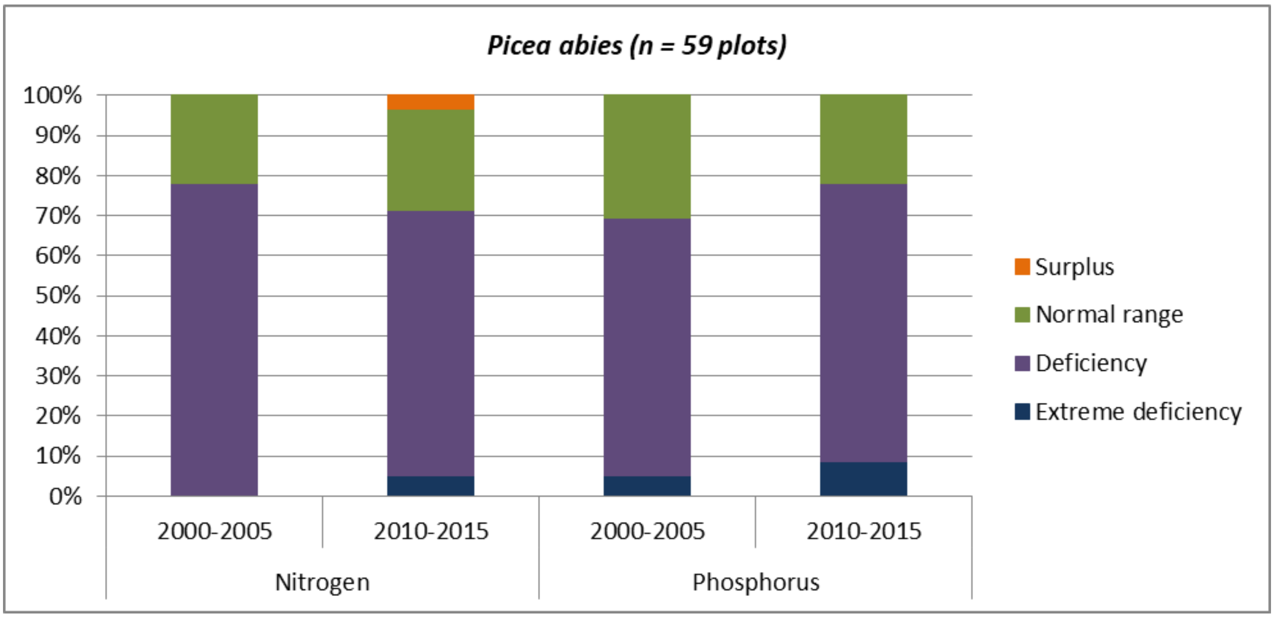


Figure 6-4: Comparison of foliar nitrogen and phosphorus concentration of Norway spruce (*P. abies*) between the periods 2000–2005 and 2010–2015, respectively

Over the complete measuring period, both nitrogen and phosphorus concentrations show a decreasing trend (Figures 6-5, 6-6). Mean foliar nitrogen values decreased from 14.2mg/g to 12.5mg/g. Mean phosphorus values decrease from 1.4mg/g to 1.1mg/g. The N:P ratios remain stable at around 10.

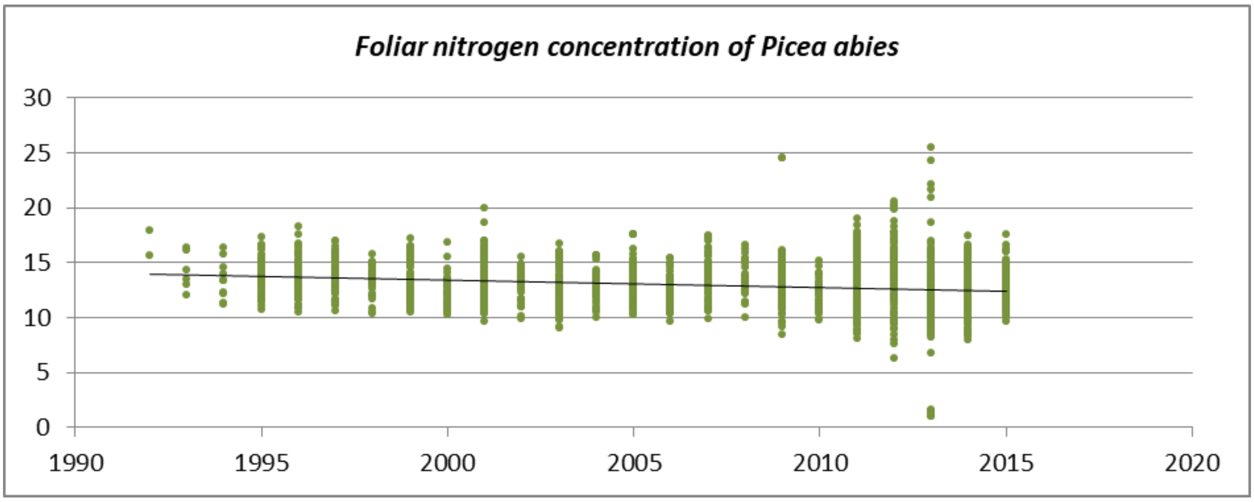


Figure 6-5: Trends in foliar N concentration (mg/g) in *Picea abies*

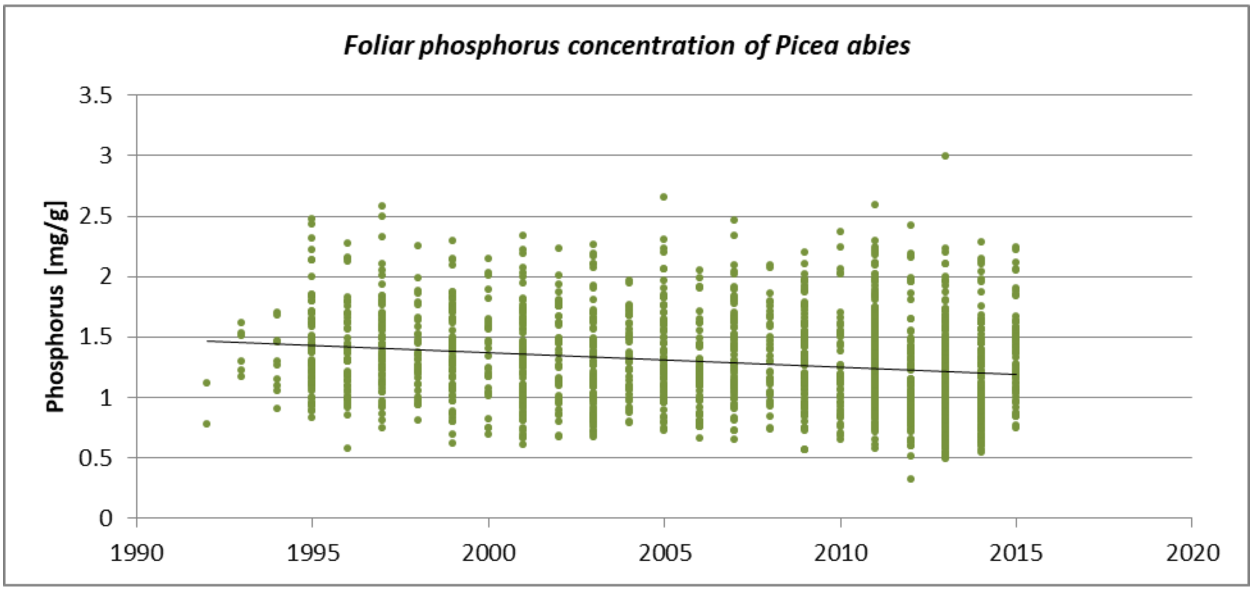


Figure 6-6: Trends in foliar P concentration (mg/g) in *Picea abies*

Scots pine (*Pinus sylvestris*)

For the 35 *Pinus sylvestris* plots there was a slight decrease in the number of plots within the surplus range (4 to 3 or 11% to 9%, respectively) and an increase in the normal range (23 to 26 or 66% to 74%, respectively) for foliar nitrogen (Figure 6-7). The number of plots in the deficiency range decreased from seven to five (20% to 14%). There was one plot in the extreme deficiency range in both time periods (3%).

For phosphorus, we find an increase in the surplus range from nil to two plots and an accompanying decrease from 23 to 21 in the normal range. The number of plots in the deficiency range remained stable (12 plots, 34%).

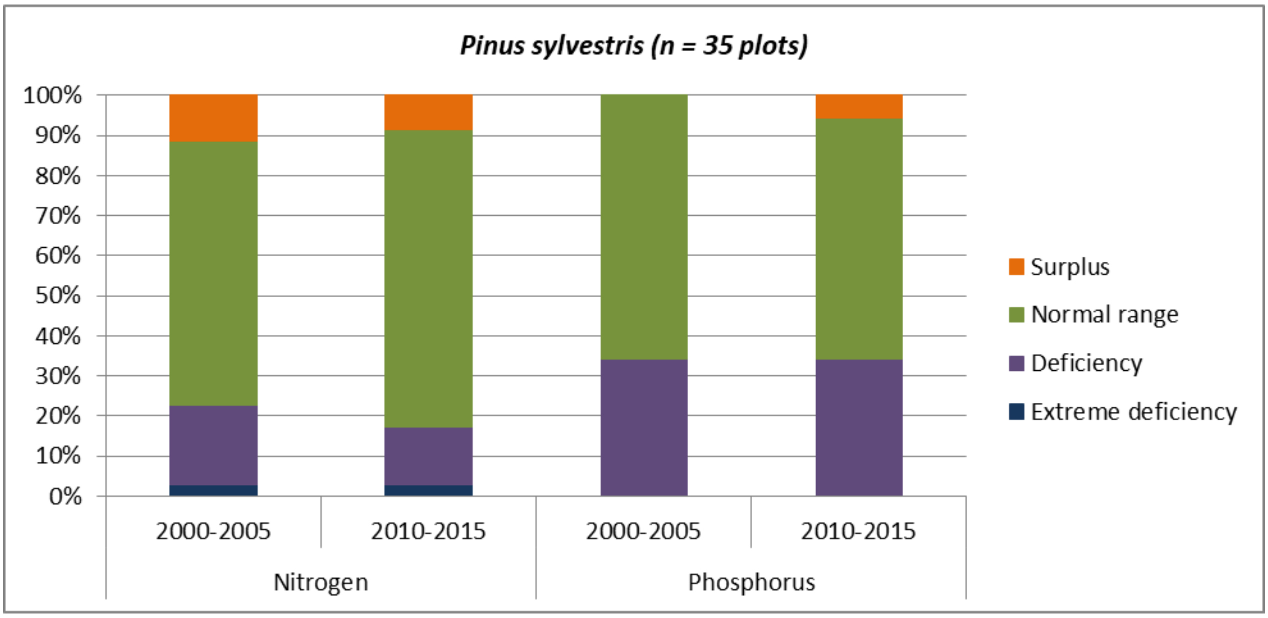


Figure 6-7: Comparison of foliar nitrogen and phosphorus concentration of Scots pine (*P. sylvestris*) between the periods 2000–2005 and 2010–2015, respectively

For Scots pine there was a very slight increase in foliar nitrogen concentration from 16mg/g to 17.1mg/g (Figure 6-8, 6-9). Foliar phosphorus remained relatively stable at 1.3mg/g.

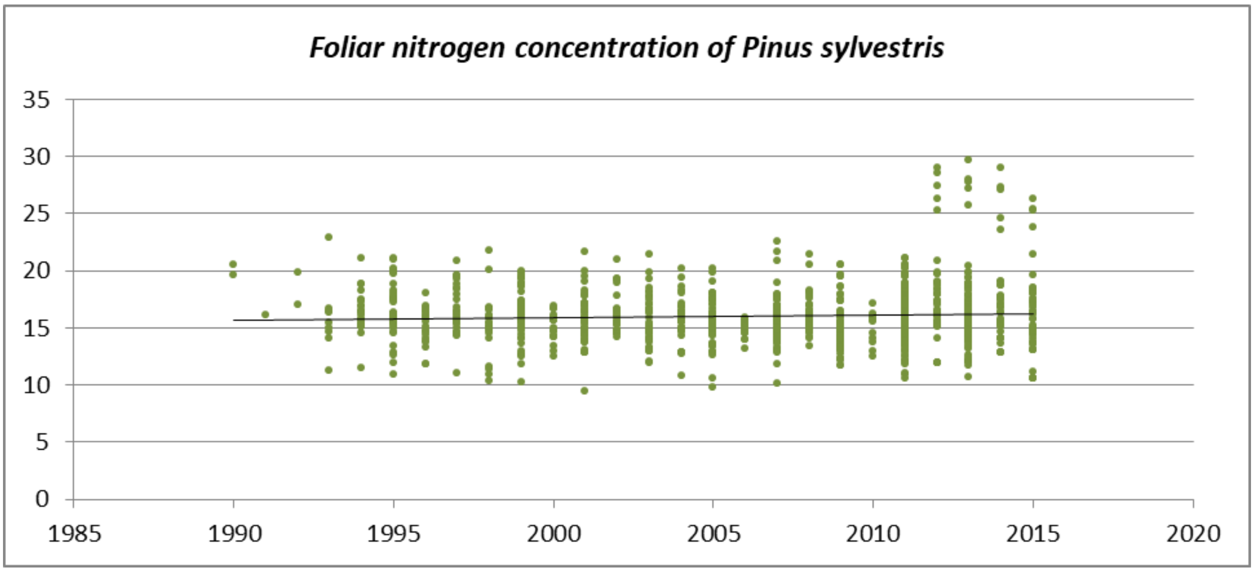


Figure 6-8: Trends in foliar N concentration (mg/g) in *Pinus sylvestris*

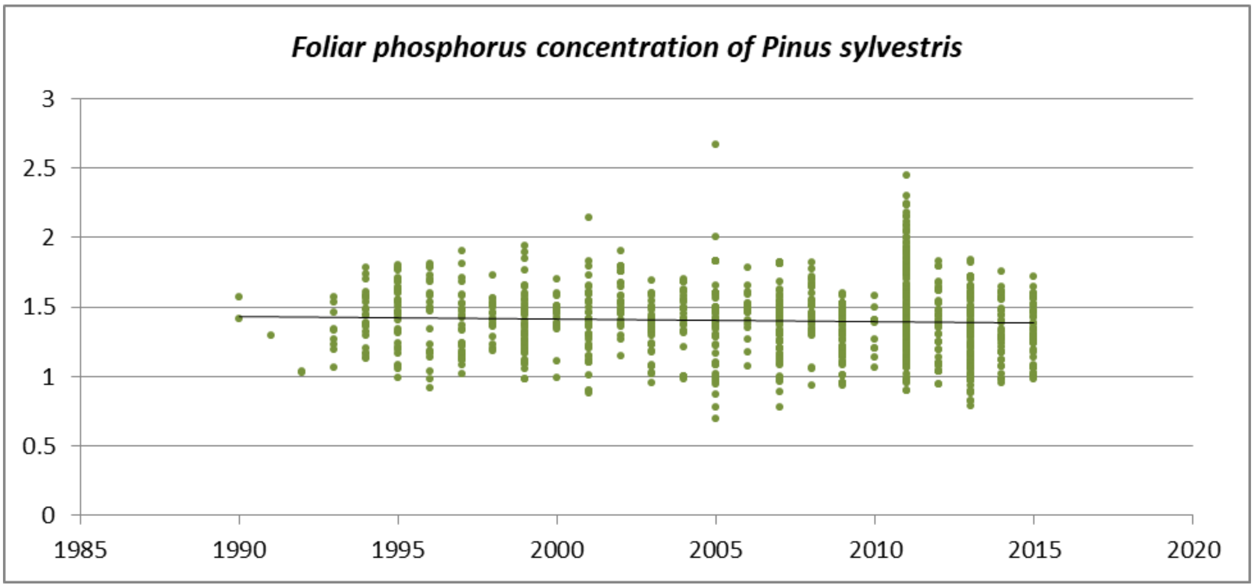


Figure 6-9: Trends in foliar P concentration (mg/g) in *Pinus sylvestris*

Foliar N:P ratio

Figure 6-10 displays a comparison of the mean N:P ratios of the three tree species in the observation period 2000–2005 and 2010–2015. In the period 2000–2005 the N:P ratio was not exceeding the normal range for any species. In contrast, in 2010–2015, the upper-limit range was reached by 45 (51%), 28 (47%), and 5 (18%) plots for beech, spruce, and pine, respectively. In 2010–2015 only spruce showed four plots below the lower limit of the foliar N:P concentration.

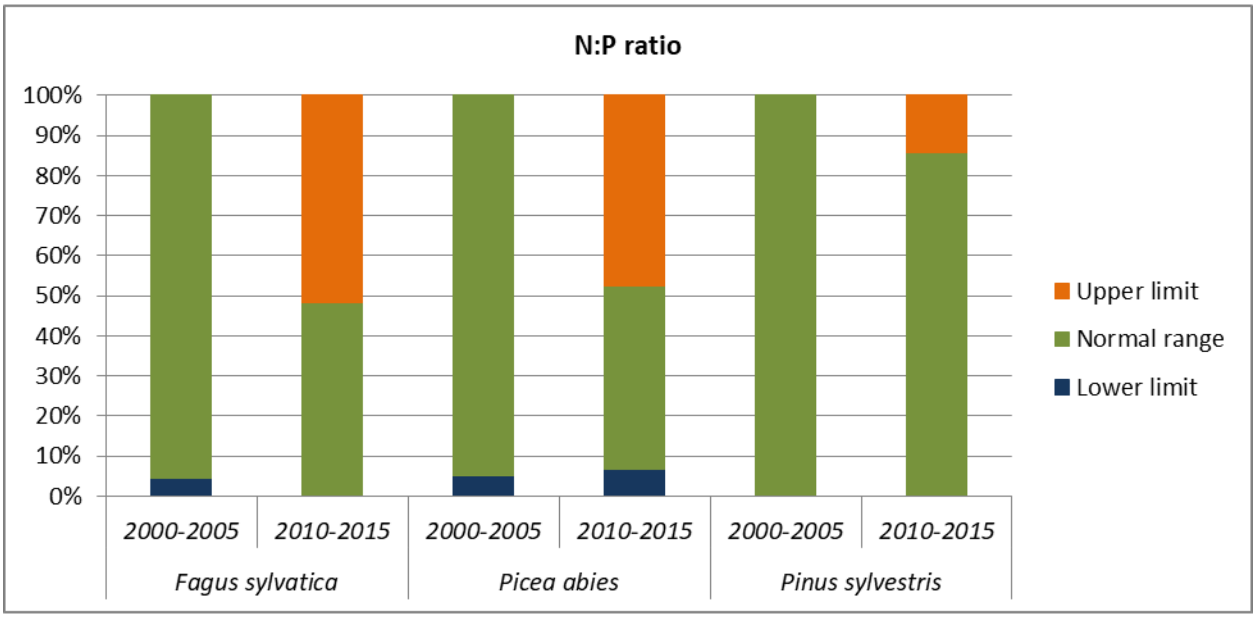
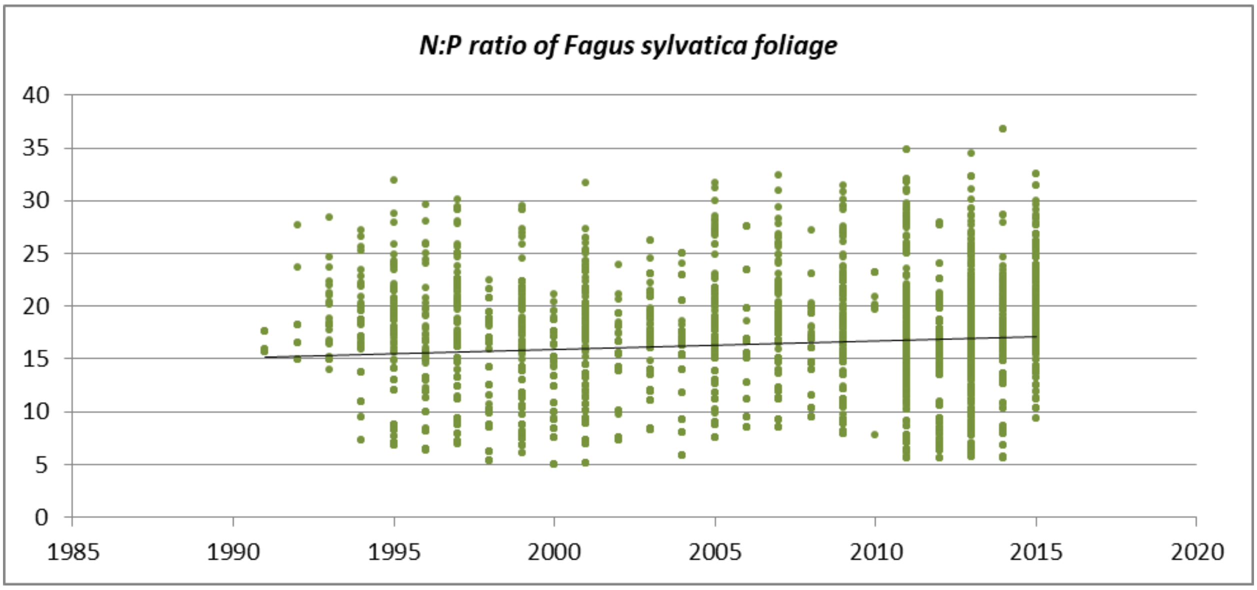
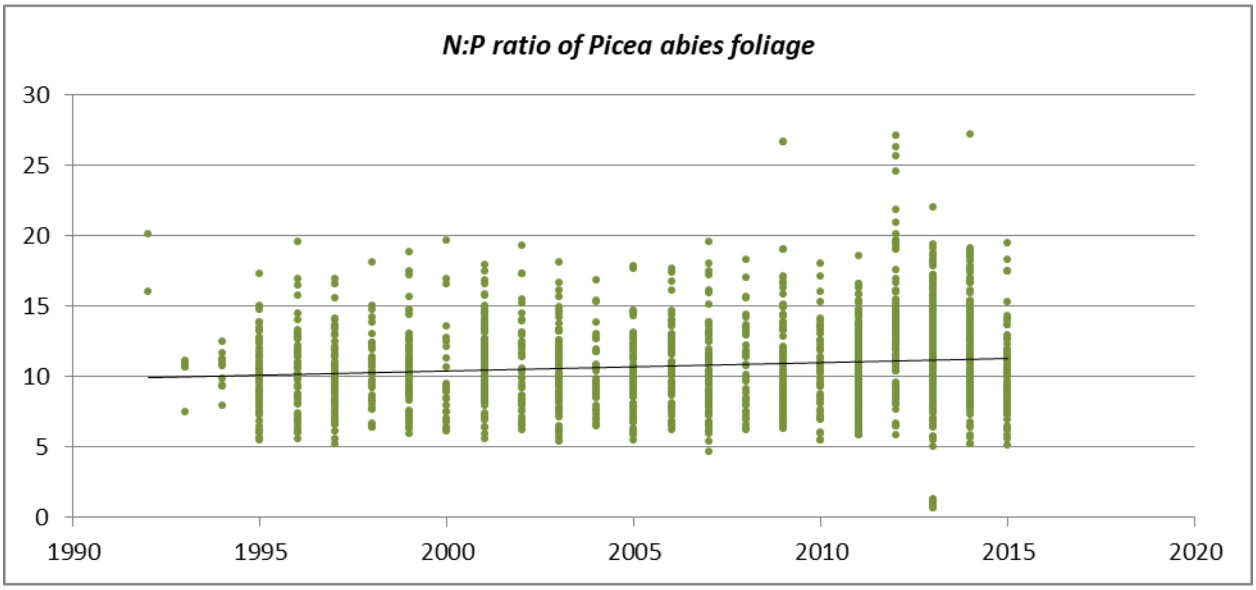


Figure 6-10: Comparison of the foliar N:P ratio in *F. sylvatica*, *P. abies*, and *P. sylvestris* between the periods 2000–2005 and 2010–2015, respectively

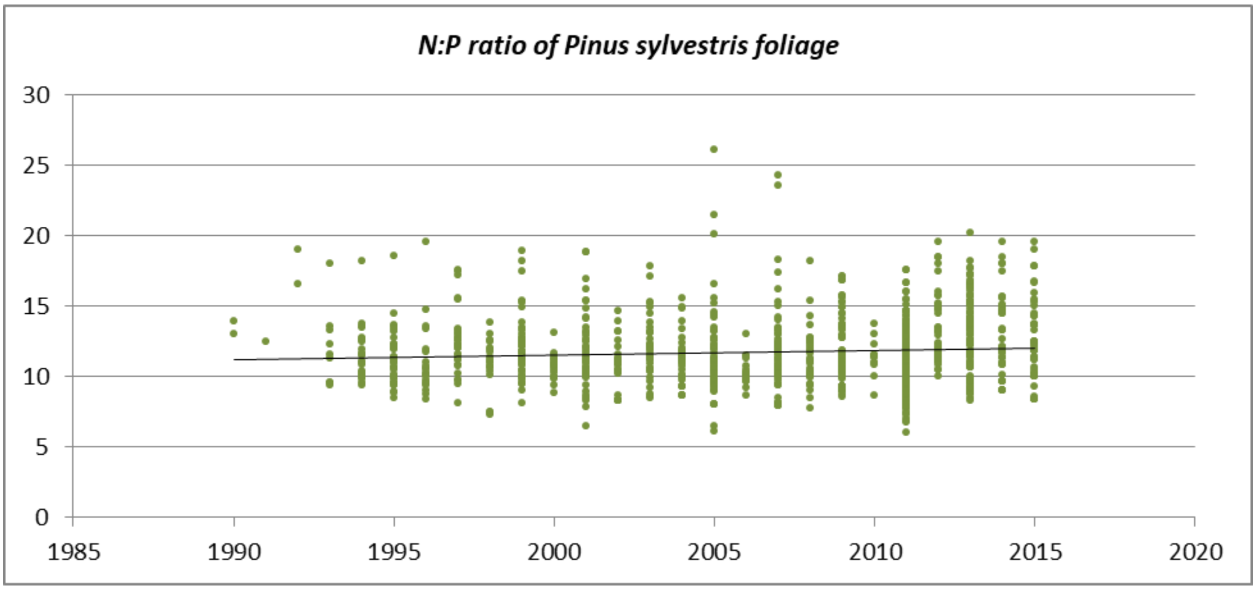
Increasing trends for the N:P ratio can be seen in all three species during 1993–2016 (Figures 6-11, 6-12, 6-13).



Figures 6-11: Trend in N:P ratio in *Fagus sylvatica* foliage



Figures 6-12: Trend in N:P ratio in *Picea abies* foliage



Figures 6-13: Trend in N:P ratio in *Pinus sylvestris* foliage

Our findings go in line with Talkner et al. (2015), who observed significant decreasing foliar P concentrations and increasing trends in foliar N:P ratios of *Fagus sylvatica* foliage; thus moving closer to the critical ranges. Also Jonard et al. (2015) found significant deterioration of P nutrition in *Fagus sylvatica* and *Pinus sylvestris,* which goes in line with the observed tendency of an increasing number of plots with critical N:P ratios. The declining trend in foliar P concentrations could be an indication of an increasing P limitation of trees and forest stands.

With regard to N, the results suggest that the supply is at least adequate on the majority of the observed Level II plots for *Fagus sylvatica* and *Pinus sylvestris*, while a larger proportion of *Picea abies* plots remains in the deficiency range. For *Fagus sylvatica,* both the normal foliar N concentration range (i.e. between adequate and optimum) and the normal range for the N:P ratio is exceeded on a large proportion of plots, indicating potentially widespread P limitation.

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7 TREE CROWN CONDITION IN 2016

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7.1 Introduction and scientific background

Tree crown defoliation and occurrence of biotic and abiotic damage are important indicators of forest health. As such, they are considered within the Criterion 2, “Forest health and vitality”, one of the six criteria adopted by Forest Europe (formerly the Ministerial Conference on the Protection of Forests in Europe – MCPFE) to provide information for sustainable forest management in Europe[2].

Defoliation surveys are conducted in combination with detailed assessments of biotic and abiotic damage causes. Unlike assessments of tree damage, which can in some instances trace the tree damage to a single cause, defoliation is an unspecific parameter of tree vitality, which can be affected by a number of anthropogenic and natural factors. Combining the assessment of damage symptoms and their causes with observations of defoliation allows for a better insight into the condition of trees, and the interpretation of the state of European forests and its trends in time and space is made easier.

This chapter presents results from the crown condition and tree damage cause assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2016, as well as long-term trends for the main species and species groups.

7.2 Methods of the 2016 survey

The assessment of tree condition in the transnational Level I network is conducted according to European-wide, harmonized methods described in the ICP Forests Manual by Eichhorn et al. (2016, see also Eichhorn and Roskams 2013). Regular national calibration trainings of the survey teams and international cross-comparison courses (ICCs) ensure the quality of the data and comparability across the participating countries (e.g. Dobbertin et al. 1997, Eickenscheidt 2015).

Defoliation

Defoliation is the key parameter of tree condition within forest monitoring describing a loss of needles or leaves in the assessable crown compared to a local reference tree in the field or an absolute, fully foliated reference tree from a photo guide. Defoliation is estimated in 5% steps, ranging from 0% (no defoliation) to 100% (dead tree). Defoliation values are grouped into five classes (Table 7-1). In the maps presenting the mean plot defoliation and in Table 7-3, class 2 is divided (> 25–40% and > 40–60%).

Table 7-1: Defoliation classes

Defoliation class	Needle/leaf loss	Degree of defoliation
0	up to 10%	None
1	> 10–25%	Slight (warning stage)
2	> 25–60%	Moderate
3	> 60–< 100%	Severe
4	100%	Dead

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[1] For contact information, please refer to the annex.

[2] http://www.foresteurope.org/docs/MC/MC_lisbon_resolution_annex1.pdf

Damage cause assessments

The damage cause assessment of trees consists of three major parts. For a detailed description, please refer to Eichhorn et al. (2016) and Timmermann et al. (2016).

- **Symptom description**
  Three main categories indicate which parts of a tree are affected: (a) leaves/needles; (b) branches, shoots, and buds; and (c) stem and collar. A further specification of the affected part is additionally provided.
- **Determination of the damage cause (causal agents / factors)**
  Main groups of causal agents are insects, fungi, abiotic factors, game and grazing, direct action of man, fire and atmospheric pollutants. In each group, a more detailed description is possible through a hierarchical coding system.
- **Quantification of symptoms (damage extent)**
  The extent is the estimated percentage of damage of the corresponding affected part of a tree.

Additional parameters

Several additional parameters are annually assessed providing information for the analysis of the crown condition data (cf. Table 3–4 in Timmermann et al. 2016).

The transnational crown condition survey in 2016

The transnational crown condition survey in 2016 was conducted on 5,396 plots in 25 countries (Table 7-2). In total, 101,959 trees were assessed in the field for defoliation. Damage cause assessments were carried out on 100,379 trees on 5,430 plots in 24 countries. Both the number of plots and the number of trees vary in the course of time, for example due to mortality or changes in the sampling design. Compared to 2015, 201 additional plots have been assessed for defoliation in 2016, because of the assessments being resumed in Spain and Montenegro, and a larger number of plots assessed in Belgium. On the other hand, no 2016 assessment data was available for this report from Andorra, Belarus, and Cyprus.

In 2016, 46.7% of the plots were dominated by broadleaved and 53.3% by coniferous trees. This distribution illustrates the natural predominance of coniferous species in boreal and mountainous regions as well as the preference of forest management for coniferous species outside their natural distribution range.

Tree species

Most Level I plots with crown condition assessments contained one (46.8%), two to three (40.6%), or four to five (10.6%) tree species per plot. Only 2.0% of the plots featured more than five species per plot.

On all Level I plots assessed in 2016, *Pinus sylvestris* (17.3%) was the most abundant tree species followed by *Picea abies* (12.5%), *Fagus sylvatica* (10.9%), *Pinus nigra* (5.0%), *Quercus petraea* (4.4%), *Q. robur* (4.3%), *Q. ilex* (3.8%), *Q. cerris* (3.2%), and *Pinus brutia* (3.1%). Some tree species belonging to the *Pinus* and *Quercus* genus were combined into species groups for further analysis:

- Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, *P. pinea*)
- Deciduous temperate oaks (*Quercus petraea* and *Q. robur*)
- Deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*)
- Evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q rotundifolia*, *Q. suber*).

Table 7-2: Number of plots assessed for defoliation from 2007 to 2016 in countries with at least one Level I crown condition survey since 2007 and number of sample trees assessed for defoliation in 2016

	Plots										Trees
Country	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2016**
Andorra	3	3	3	3	3	3	11	11	12		
Austria				135							
Belarus	400	400	409	410	416		373		377		
Belgium	27	26	26	9	9	8	8	8	8	53	582
Bulgaria	104	98	159	159	159	159	159	159	159	159	5 353
Croatia	83	84	83	83	92	100	105	103	95	99	2 376
Cyprus	15	15	15	15	15	15	15	15	15		
Czechia	132	136	133	132	136	135		138	136	136	3 400
Denmark	19	19	16	17	18	18	18	18	17	17	393
Estonia	93	92	92	97	98	97	96	96	97	98	2 421
Finland	593	475	886	931	717	784					
France	504	508	500	532	544	553	550	545	542	533	10 676
Germany	420	423	412	411	404	415	416	422	424	421	10 101
Greece			97	98				57	47	23	536
Hungary	72	72	73	71	72	74	68	68	67	67	1 498
Ireland	30	31	32	29		20					
Italy	238	236	252	253	253	245	247	244	234	246	4 882
Latvia	93	92	207	207	203	203	115	116	116	115	1 723
Lithuania	62	70	72	75	77	77	79	81	81	82	1 964
Luxembourg	4	4					4	4	4	4	96
Montenegro				49	49	49	49			49	1 176
Netherlands			11	11							
Norway	476	481	487	491	493	496	461	488	411	476	2 651
Poland	458	453	376	374	367	369	364	365	361	353	7 035
Romania	218		227	239	242	240	236	240	242	242	5 802
Russian Fed.			365	288	292						
Serbia	125	123	122	121	119	121	121	128	127	127	2 952
Slovakia	107	108	108	108	108	108	108	106	105	101	4 203
Slovenia	44	44	44	44	44	44	44	44	44	44	1 056
Spain	607	607	620	620	620	620	620	620		620	14 880
Sweden			789	752	571	570	684	842	837	698	1 870
Switzerland	48	48	48	48	47	47	47	47	47	47	790
Turkey	43	396	560	554	563	578	583	531	590	586	13 543
United Kingdom	32			76							
TOTAL	**5 063**	**5 057**	**7 224**	**7 442**	**6 731**	**6 148**	**5 581**	**5 496**	**5 195**	**5 396**	**101 959**

Statistical analyses

For the calculation of the overall mean defoliation for all species and species groups (Table 7-3), all assessed trees were taken into account. For the calculation of the mean plot defoliation of all species, only plots with a minimum number of three trees were analysed. For analyses at species level, three trees per species had to be present per plot. These criteria are consistent with earlier evaluations (e.g. Wellbrock et al. 2014, Becher et al. 2014) and partly explain the discrepancy between the number of trees in Table 7-2 and in the online supplementary material[1].

Trends in defoliation over time presented in this chapter were calculated according to Sen (1968) and their significance tested by the non-parametric Mann-Kendall test (tau). These methods are appropriate

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[1] http://icp-forests.net/page/icp-forests-technical-report

for monotonous, single-direction trends without the need to assume any particular distribution of the data. Due to their focus on median values and corresponding robustness against outliers (Sen 1968, Drápela & Drápelová 2011, Curtis & Simpson 2014), the results are less affected by single trees or plots with unusually high or low defoliation. The regional Sen's slopes for Europe were calculated according to Helsel & Frans (2006). For both the calculation of Mann-Kendall's tau and the plot-related as well as the regional Sen's slopes, the rkt package (Marchetto 2014) in the R version 3.1.3 (R Core Team 2015) was used.

Figures 7-2a-j show (1) the annual mean defoliation per plot, (2) the mean across plots and (3) the trend of defoliation based on the regional Sen's slope calculations. For the Mann-Kendall test, a significance level of $p \leq 0.05$ had been applied. All Sen's slope calculations and yearly over-all mean defoliation values were based on consistent plot selections with a minimum of three trees per species and per plot. Plots were included if at least 20 years with assessments were available in the period 1992–2016. Maps of defoliation trends for the period 2011–2016 (minimum assessment length of 4 years) can be found in the online supplementary material. Statistical analyses were performed with R version 3.1.3 (R Core Team 2015; Mann-Kendall test and Sen's slope) and SAS 9.4 (SAS Institute Inc. 2015).

National surveys

In addition to the transnational surveys, national surveys are conducted in many countries, relying on denser national grids and aiming at the documentation of forest condition and its development in the respective country (Table 7-3). Since 1986, densities of national grids between 1x1 km and 32x32 km have been used due to differences in the size of forest area, structure of forests and forest policies. The results of defoliation assessments on national grids are presented in the online supplementary material[1]**.** Comparisons between the national surveys of different countries should be made with great care because of differences in species composition, site conditions, and methods applied.

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[1] http://icp-forests.net/page/icp-forests-technical-report

Table 7-3: Information on the monitoring design for the national crown condition surveys in the participating countries in 2016

Country	Total area (1000 ha)	Forest area (1000 ha)	Area surveyed (1000 ha)	Coniferous forest (1000 ha)	Broadleaf forest (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	No data available for 2016							
Andorra	47	18	18	15	2	4x4	12	298
Austria	No data available for 2016							
Belarus	No data available for 2016							
Belgium-Flanders	1351	146	146			4x4	71	1581
Belgium-Wallonia	1684	555		224	260	varying	45	390
Bulgaria	11100	4223	4223	1261	2962	4x4/16x16	159	5549
Croatia	5654	2061		321	1740	16x16	99	2376
Cyprus	925	298	138	172	0	16x16	15	361
Czechia	7887	2666	2666	1956	710		136	5173
Denmark	4310	599		306	293		352	1915
Estonia	4510	2309	2309	1158	1151	16x16	98	2421
Finland	No data available for 2016							
France	54883	15840	13100	4041	9884	16x16	535	10904
Germany	35721	11419	10630	5900	4727	16x16	421	10133
Greece	No data available for 2016							
Hungary	9300	1939	1939	209	1730	16x16	78	1872
Ireland	No data available for 2016							
Italy	30128	8675		1735	6940	16x16	246	4895
Latvia	6459	3162	3162	1453	1710	16x16	115	1723
Lithuania	6529	2187	2058	1148	910	4x4/16x16	1006	5896
Luxembourg	259	91	86	27	59	4x4	49	1176
FYRO Macedonia	No data available for 2016							
Rep. of Moldova	3384	401	375	8	367	varying	611	14342
Montenegro	1381	827	827	207	620	16x16	49	1176
Netherlands	No data available for 2016							
Norway	32376	12100	12100	7061	5039	3x3	1854	20931
Poland	31268	9198	9198	6329	2869	8x8	2001	40020
Portugal	No data available for 2016							
Romania	23839	6233	6233	1873	4360	16x16	242	5807
Russian Fed.	No data available for 2016							
Serbia	8836	2360	1868	179	2181	4x4/16x16	130	2973
Slovakia	4904	2014	2014	768	1246	16x16	103	3539
Slovenia	2014	1209	1209	457	752	16x16	44	1056
Spain	50471	18173		6600	9626	16 x 16	620	14880
Sweden	40800	28100	17500	19400	1700	varying	3452	7883
Switzerland	4129	1279		778	501		47	1039
Turkey	77846	21537	9057	13158	8379	16x16	586	13547
Ukraine	No data available for 2016							
United Kingdom	No data available for 2016							

7.3 Results of the transnational crown condition survey

Defoliation

In 2016, 101,959 trees were assessed for defoliation (Table 7-4). The overall mean defoliation for all species was 21.1%; with a slight improvement in defoliation for the conifers compared to 2015, but a worsening for broadleaves. Broadleaved trees showed a slightly higher mean defoliation than coniferous trees (22.1% vs. 20.1%). Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' or 'slight' (77.6%) than broadleaves (71.9%).

Among the main tree species and tree species groups (Table 7-4), evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (25.0% and 23.4%, respectively). Mediterranean lowland pines and Austrian pine had the highest mortality rates (1.9% and 1.1%, respectively). Austrian pine and common beech had the lowest mean defoliation (19.5% and 19.6%, respectively). Scots pine had the highest percentage (79.6%) of not or only slightly defoliated trees (≤ 25% defoliation) while deciduous temperate oaks had the lowest (68.0%). The strongest increase in defoliation from 2015 to 2016 occurred in common beech (+3.1%). Deciduous (sub-) Mediterranean oaks and evergreen oaks had the largest decrease in defoliation (-3.9 and -6.5%, respectively), however, the sample of trees changed much between 2015 and 2016 (3,547 vs. 7,746 trees for deciduous (sub-) Mediterranean oaks and 795 vs. 4,607 trees for evergreen oaks), making direct comparisons impossible. However, when comparing 2016 data with 2014 data, the differences are not very large.

Table 7-4: Percentage of trees assessed in 2016 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2015 in parentheses) and the number of trees in each group. Dead trees were excluded when calculating mean defoliation.

Main species or species groups	Class 0	Class 1	Class 2-1	Class 2-2	Class 3	Class 4	Mean defoliation	No. of trees
	0-10	>10-25	>25-40	>40-60	>60	dead		
Common beech *(Fagus sylvatica)*	28.6	39.9	20.8	7.6	2.5	0.6	22.7 (+3.1)	11,089
Deciduous temperate oaks	22.2	45.8	23.3	6.0	2.3	0.5	23.4 (+0.0)	8,888
Dec. (sub-) Mediterranean oaks	30.4	46.4	15.5	4.8	1.9	0.9	20.2 (-3.9)	7,746
Evergreen oaks	10.3	59.5	19.8	6.8	3.0	0.7	25.0 (-6.5)	4,607
Other broadleaves	33.4	40.8	14.1	4.9	3.9	3.0	21.0 (+0.6)	18,455
Scots pine *(Pinus sylvestris)*	26.0	53.6	13.7	3.8	1.8	1.0	20.4 (-1.0)	17,618
Norway spruce *(Picea abies)*	35.8	37.1	19.1	5.3	1.6	1.0	19.9 (-0.3)	12,769
Austrian pine (*Pinus nigra*)	36.7	42.0	12.5	4.7	3.0	1.1	19.8 (+0.3)	5,136
Mediterranean lowland pines	17.6	60.6	14.5	4.2	1.3	1.9	21.3 (+0.8)	8,266
Other conifers	40.4	39.2	13.4	4.0	2.2	0.8	18.6 (+0.9)	7,385
TOTAL								
Broadleaves	27.9	44.0	17.9	5.8	2.9	1.5	22.1 (0.8)	50,785
Conifers	30.2	47.4	15.0	4.4	1.9	1.1	20.1 (-0.1)	51,174
All species	**29.0**	**45.7**	**16.4**	**5.1**	**2.4**	**1.3**	**21.1 (0.4)**	**101,959**

Mean defoliation of all species at plot level is shown in Figure 7-1. Almost three quarters (70.8%) of all plots had a mean defoliation up to 25%, and 1.3 % of the plots showed severe defoliation (more than 60%). Plots with high mean defoliation (>40%) were primarily found in southern (Mediterranean) France and Corsica, northern Italy, coastal Croatia, western Bulgaria and the Czech Republic. Plots with low mean defoliation were found across Europe, but mainly in south-eastern Norway and southern Sweden, Estonia, northern Germany, northern Croatia, Romania, and Serbia, as well as in Turkey.

The following sections describe the species-specific mean plot defoliation in 2016 and the over-all trend and yearly mean plot defoliation from 1992 to 2016. For maps on defoliation of individual tree species in 2016, please refer to the online supplementary material[1].

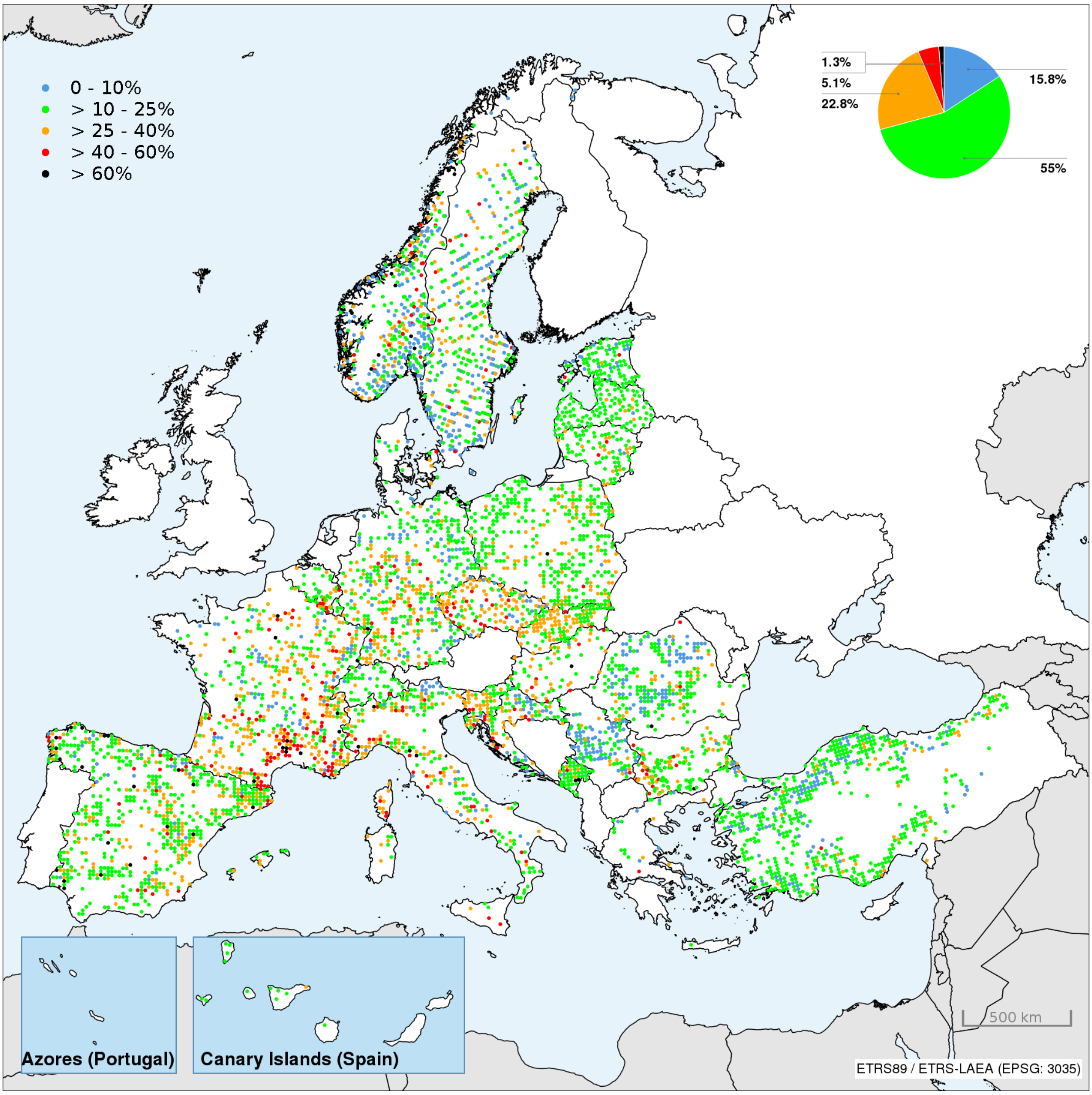

Figure 7-1: Mean plot defoliation of all species in 2016

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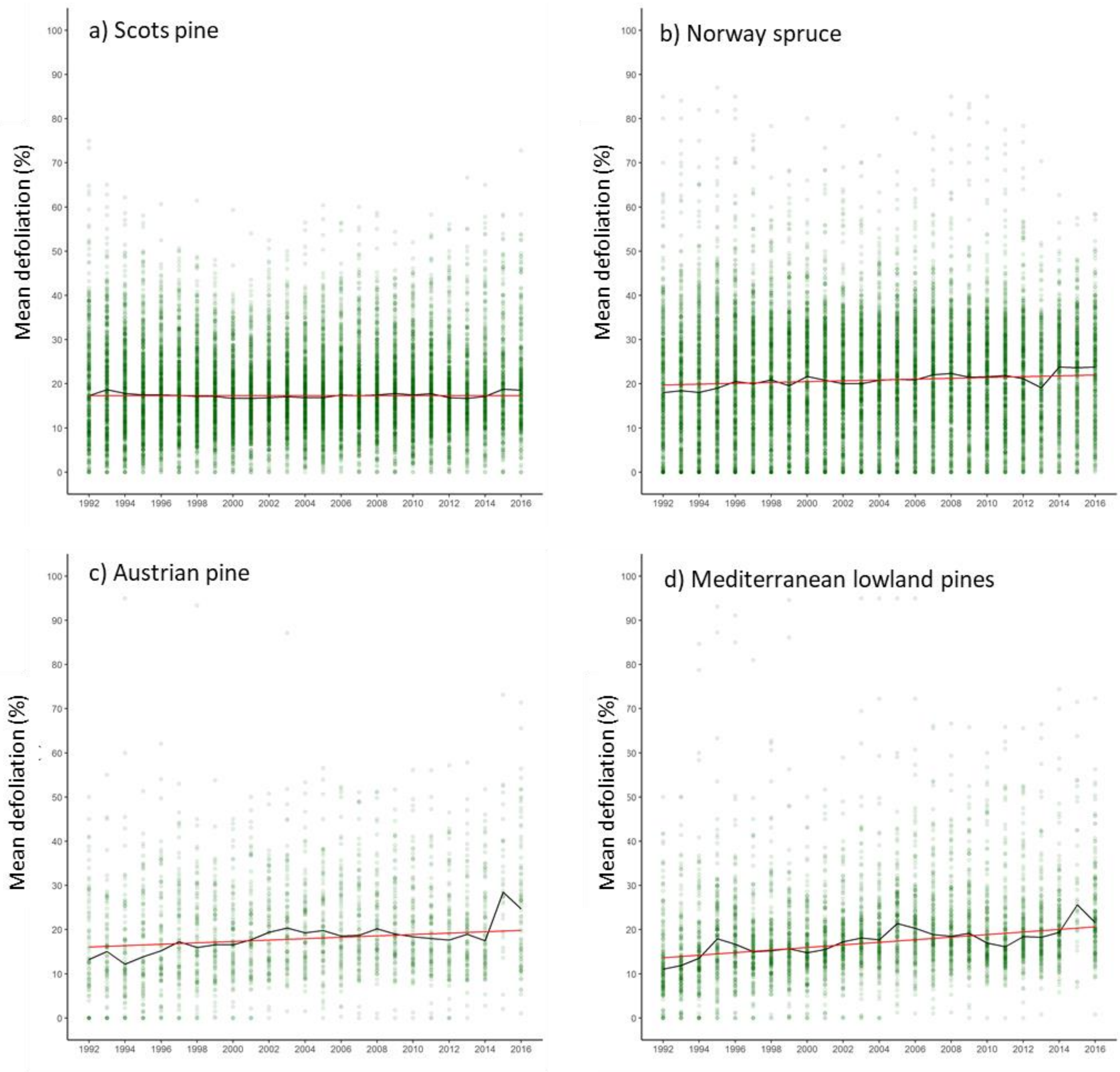
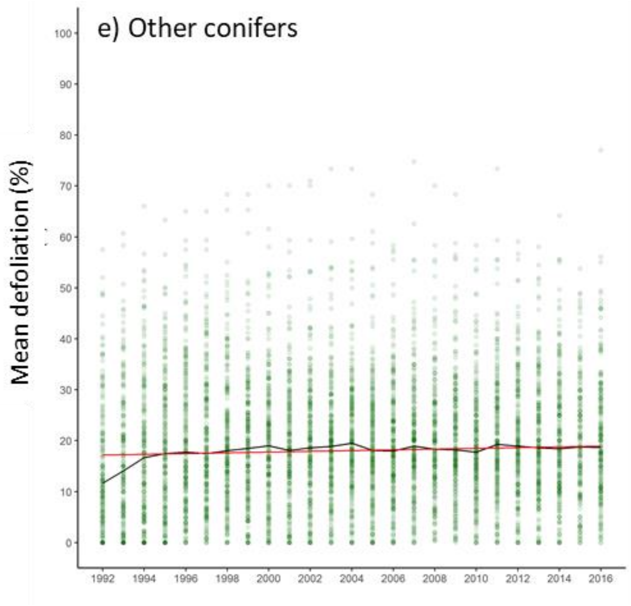
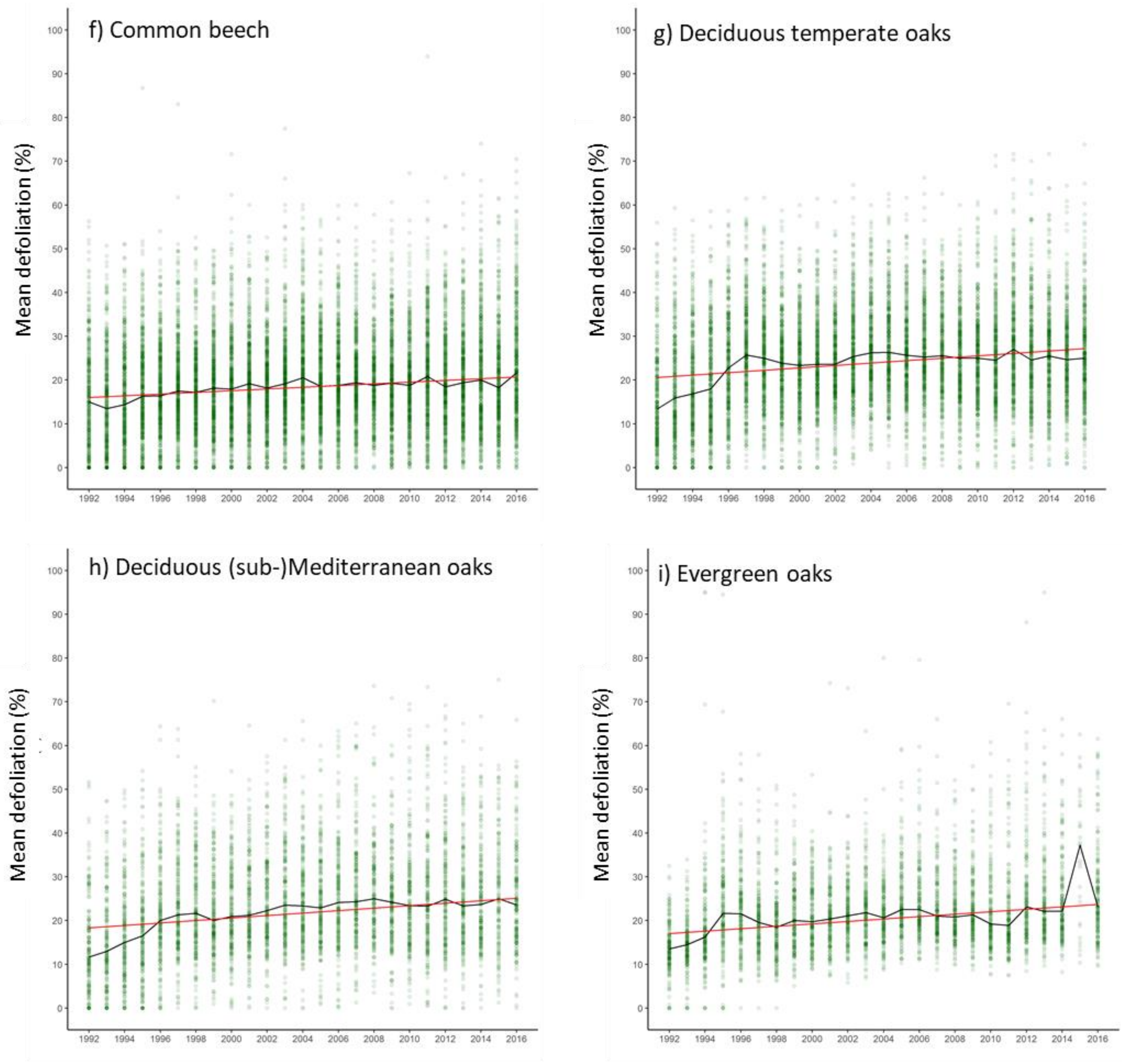
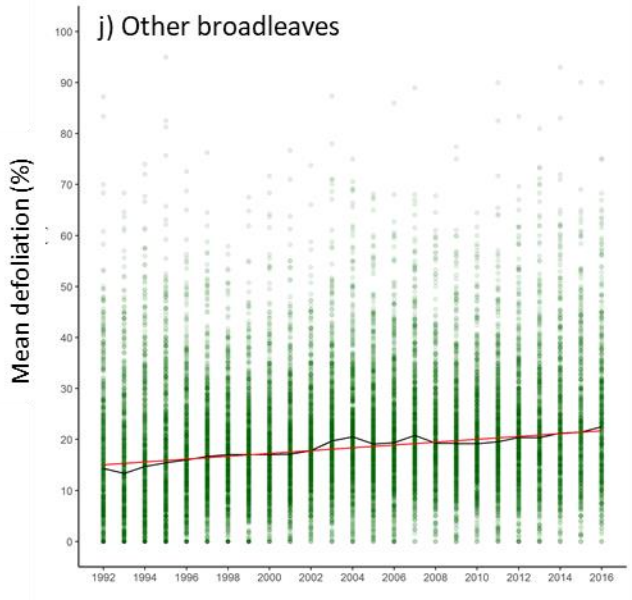
[1] http://icp-forests.net/page/icp-forests-technical-report





Figures 7-2 a-e: Over-all trend (red line) and annual mean defoliation across plots (black line) at Level I plots; points represent annual plot mean values, for clarity these are not interconnected from year to year: (a) Scots pine (regional Sen's slope = 0.0, *p* = 0.318) (b) Norway spruce (regional Sen's slope = 0.096, *p* < 0.001), (c) Austrian pine (regional Sen's slope = 0.156, *p* < 0.001) (d) Mediterranean lowland pines (regional Sen's slope = 0.292, *p* < 0.001) (e) other conifers (regional Sen's slope = 0.072, *p* < 0.001).





Figures 7-2 f-j: Over-all trend (red line) and annual mean defoliation across plots (black line) at Level I plots; points represent annual plot mean values, for clarity these are not interconnected from year to year: (f) Common beech (regional Sen's slope = 0.195, $p < 0.001$) (g) Deciduous temperate oaks (regional Sen's slope = 0.275, $p < 0.001$) (h) Deciduous (sub-) Mediterranean oaks (regional Sen's slope = 0.281, $p < 0.001$), and (i) Evergreen oaks (regional Sen's slope = 0.278, $p < 0.001$), (j) other broadleaves (regional Sen's slope = 0.278, $p < 0.001$).

Scots pine

Scots pine (*Pinus sylvestris*) was the most frequently assessed tree species in the Level I network in 2016. It has a wide ecological niche due to its ability to grow on dry and nutrient poor soils and has frequently been used for reforestation. Scots pine is found over large parts of Europe from northern Scandinavia to the Mediterranean region and from Spain to Turkey (and is also distributed considerably beyond the UNECE region).

More than three-fourths of the Scots pine plots (77.8%) showed no or only slight defoliation (≤ 25% defoliation; please refer to the online supplementary material, Figure S1-1). Defoliation on 21.6% of the plots was moderate (>25-60% defoliation) and on 0.6% of the plots severe. Plots with the lowest mean defoliation were primarily found in southern Norway and northern Germany, whereas plots with comparably high defoliation were located in the Czech Republic, Slovakia, southern France, and Bulgaria.

From 1992 to 2016, there was no over-all trend in mean plot defoliation of Scots pine (regional Sen's slope = 0.0, p = 0.321; Figure 7-2a). The mean defoliation across plots showed only small fluctuations from year to year except in the last two years when it was slightly higher than the long-term mean.

Norway spruce

Norway spruce (*Picea abies*) is the second most frequently assessed species on the Level I plots. The area of its distribution within the participating countries ranges from Scandinavia to northern Italy and from north-eastern Spain to Romania. Favouring cold and humid climate, Norway spruce at the southern edge of its distribution area is found only at higher elevations.

In 2016, mean defoliation on most of the Norway spruce plots (68.1%) was relatively low (≤ 25% defoliation; please refer to the online supplementary material, Figure S1-2). As much as 25.2% of all Norway spruce plots showed a defoliation of up to 10%. Defoliation on 31.2% of the plots was moderate (>25-60% defoliation) and severe defoliation was recorded on only 0.7% of the plots. Plots with low mean defoliation were found e.g. in Norway, eastern France, and Romania. Clusters of plots with mean defoliation values above 25% were mainly found in Slovakia, in the mountainous regions of the Czech Republic, in the Black Forest and other mountainous regions in Germany, in central and western parts of Slovenia, in the French Alps, and more scattered in Norway and Sweden.

From 1992 to 2016, a very slight but statistically significant increasing trend in mean plot defoliation of less than 1 percentage point every 10 years was observed (regional Sen's slope = 0.096 , $p < 0.001$; Figure 7-2b). Somewhat larger deviations from the trend line can be observed since 2013.

Austrian (Black) pine

Austrian pine (*Pinus nigra*) is one of the most important native conifers in southern Europe, growing predominantly in mountain areas from Spain in the west to Turkey in the east, with scattered occurrences as far north as central France and northern Hungary. This species can grow in both dry and humid habitats with considerable tolerance for temperature fluctuations. Two subspecies are recognized, along with a number of varieties, adapted to different environmental conditions.

In general, Austrian pine shows very good vitality, with mean defoliation of up to 25% on 77.2% of the plots (please refer to the online supplementary material, Figure S1-3). Defoliation was moderate on 20.7% of the plots (>25-60% defoliation) and severe on 2.1% of the plots. Plots with less than 10% mean defoliation are mostly located in Turkey. Areas with higher defoliation of Austrian pine were south-eastern France, coastal Croatia and western Bulgaria.

From 1992 to 2016, the over-all trend in defoliation in Austrian pine has been increasing on average by 1.6 percentage points every 10 years with high statistical significance (regional Sen's slope = 0.156, $p < 0.001$; Figure 7-2c). Inter-annual fluctuations around the mean trend are quite large. The deviation in 2015, however, was caused by a lack of data from Spain.

Mediterranean lowland pines

Four pine species are included in the group of Mediterranean lowland pines: Aleppo pine (*Pinus halepensis*), maritime pine (*P. pinaster*), stone pine (*P. pinea*), and Turkish pine (*P. brutia*). Most plots dominated by Mediterranean lowland pines are located in Spain, France, and Turkey. Aleppo and maritime pine are more abundant in the western parts, and Turkish pine in the eastern parts of this area.

In 2016, three out of four plots with Mediterranean lowland pines (74.9%) displayed defoliation of up to 25% (please refer to the online supplementary material, Figure S1-4), although plots with very low defoliation (≤10%) were rare. These plots were mostly located in Turkey, where the overall vitality of lowland pines was very good. Plots with moderate to high mean defoliation values (>40% defoliation) were mostly concentrated in the area from the north-eastern tip of Spain, through south-eastern France, to western Italy, while most of the plots with severe defoliation (>60%) were located in Spain.

From 1992 to 2016 there was an average increase in the trend in mean plot defoliation of almost 3 percentage points every 10 years (regional Sen's slope = 0.292, $p < 0.001$; Figure 7-2d). High defoliation compared to the long-term trend occurred in 1995 and 2005, after which it usually takes two to three years for the crown to recover. Data from 2015 should be interpreted with care as a lack of data from Spain affected the overall results.

Common beech

Common beech (*Fagus sylvatica*) is the most frequently assessed deciduous tree species within the ICP Forests monitoring programme. It is found on Level I plots from southern Scandinavia in the North to southernmost Italy, and from the Atlantic coast of northern Spain in the West to the Bulgarian Black Sea coast in the East.

In 2016, there were as much as 16.7% of common beech plots with less than 10% mean plot defoliation, most of them were located in Romania (please refer to the online supplementary material, Figure S1-5). On less than half of the monitored plots (45.4%), trees were slightly defoliated (>10–25% defoliation), a reduction compared to last year. On the other hand, there were as much as 10.8% of plots with mean defoliation >40–60%, and 1% with severe defoliation (>60%). These plots were predominantly located in Germany, France, Italy, Slovenia, and Bulgaria.

From 1992 to 2016, the over-all trend in mean plot defoliation in beech has been slightly but significantly increasing by approximately 2 percentage points every 10 years (regional Sen's slope = 0.195, $p < 0.001$; Figure 7-2e). There were only a few larger deviations from this trend, in 1993/1994, 2004, and 2015. In 2004, for example, the annual over-all mean defoliation was more than 4 percentage points higher than the trend, possibly as a result of the drought in the preceding year which had affected large parts of Europe (Ciais et al. 2005, Seidling 2007). In 2016, the mean value is again close to the trendline.

Deciduous temperate oaks

Deciduous temperate oaks include pedunculate and sessile oak (*Quercus robur* and *Q. petraea*) and their hybrids. They cover a large geographical area in the UNECE region: from southern Scandinavia to southern Italy and from the northern coast of Spain to the eastern parts of Turkey.

In 2016, mean defoliation was up to 25% on more than half of the plots (59.2%), moderate mean defoliation (>25–60% defoliation) was recorded on 40.1% of plots and severe defoliation (i.e. more than 60% defoliation) in 0.6% of the plots (please refer to the online supplementary material, Figure S1-6). Plots with moderate to severe defoliation are located mostly in France, but also scattered throughout Europe. Therefore it is difficult to discern any broader geographical pattern – the defoliation of temperate oaks seems to be mostly dependent on local conditions.

The development of mean plot defoliation of deciduous temperate oaks is characterized by relatively large deviations of the annual plot mean to the over-all trend in the period 1992 to 2016, with a statistically significant increase of approximately 3 percentage points every ten years (regional Sen's slope = 0.275, $p < 0.001$; Figure 7-2f). A constant increase of defoliation between 1992 and 1997 has somewhat levelled off by the year 2000, and in recent years, especially after 2012, we see some crown recovery. Generally the changes in the defoliation status are not very fast for deciduous temperate oaks and it typically takes several years for their crown to recover. A good example is the change in defoliation status in the drought year 2003 followed by a delayed recovery.

Deciduous (sub-) Mediterranean oaks

The group of deciduous (sub-) Mediterranean oaks includes Turkey oak (*Quercus cerris*), Hungarian or Italian oak (*Q. frainetto*), downy oak (*Q. pubescens*) and Pyrenean oak (*Q. pyrenaica*). The range of distribution of these oaks is confined to southern Europe, as indicated by their common names.

In 2016, 15.5% of the plots had a mean defoliation of up to 10%, and further 54.5% had between 10 and 25% defoliation, yielding a total of 70% of the plots with defoliation up to 25% (please refer to the online supplementary material, Figure S1-7). Country-wise, the best vitality of submediterranean oaks was recorded in Serbia, while the defoliation was highest in south-eastern France. Roughly a third (29.8%) of plots showed moderate mean defoliation, and only 0.2% severe.

From 1992 to 2016 the over-all trend in mean plot defoliation of deciduous (sub-) Mediterranean oaks showed an increase of approximately 3 percentage points every 10 years (regional Sen's slope = 0.281, $p < 0.001$; Figure 7-2g). Mean plot defoliation strongly increased from 1992 to 1996 before levelling off in the following years, with values generally above the trendline in the period 1996–2012, and below in the more recent years.

Evergreen oaks

The group of evergreen oaks consists of kermes oak (*Quercus coccifera*), holm oak (*Q. ilex*), *Q. rotundifolia* and cork oak (*Q. suber*). The occurrence of this species group as a typical element of the sclerophyllous woodlands is confined to the Mediterranean basin.

In 2016, evergreen oaks were on average not or only slightly defoliated on 62.0 % of the plots (please refer to the online supplementary material, Figure S1-8). Moderate defoliation was recorded on 36.4% of plots. The majority of plots with defoliation over 40% were located in France, Corsica, and throughout Spain.

From 1992 to 2016 evergreen oak plots showed an increase in the over-all trend in mean defoliation similar to other oaks with 3 percentage points every ten years (regional Sen's slope of 0.278, $p < 0.001$; Figure 7-2h). The development of defoliation of evergreen oaks shows several positive and negative deviations from the trend. A large deviation from the trend in 2015 as well as the steep positive slope of the trendline in the last year's calculations reflect the importance of assessments on Spanish plots which are significantly influencing the overall data. In 2016 the over-all plot mean for evergreen oaks is again closer to the trendline.

Damage causes

In 2016, damage cause assessments were carried out on 100,379 trees in 5,430 plots and 24 countries. On 46,965 trees (46.8%) at least one symptom of damage was found. In total, 63,374 observations of damage were recorded with potentially multiple damage symptoms per tree. On 1,167 plots no damage was found on any tree; 1,217 trees (1.2%) were dead.

The number of damage symptoms on any individual tree can be more than one, therefore the number of cases analysed varies depending on the parameter. The average number of recorded damage symptoms per assessed tree was 0.46 for Norway spruce, 0.51 for Austrian pine, 0.58 for Mediterranean lowland pines, 0.60 for Scots pine, 0.77 for Common beech and deciduous (sub-) Mediterranean oaks, 0.90 for deciduous temperate oaks and 1.00 for evergreen oaks.

Symptom description and damage extent

Most of the 63,374 damage symptoms reported were observed on leaves of broadleaved trees (34.2%), followed by twigs and branches (24.8%), and stems (19.2%; Figure 7-3). Needles were also often affected (16.2%), while roots and collar and shoots and buds were less frequently affected (2.7% and 1.9%, respectively).

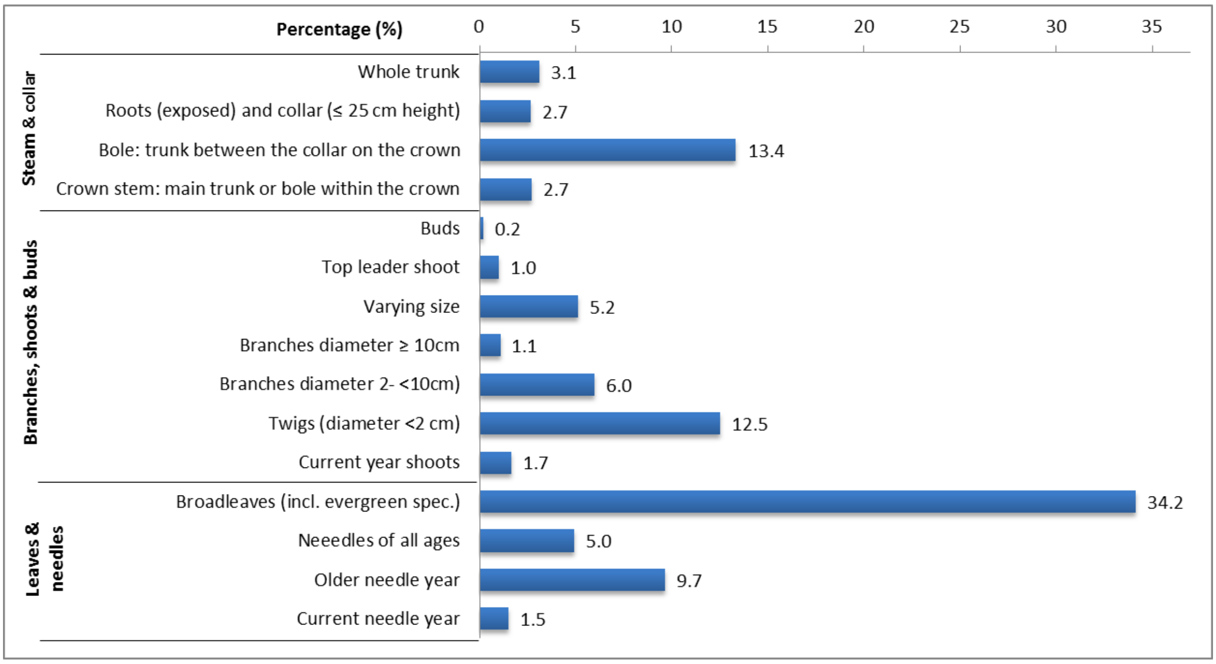


Figure 7-3: Damage symptoms according to specifications of the affected part of a tree (n=63,374). Multiple affected parts per tree were possible.

More than half (53.3%) of all recorded damage symptoms had an extent of up to 10%, 38.2% had an extent between 10% and 40%, and 8.5% of the symptoms covered more than 40% of the affected part of a tree.

Causal agents and factors responsible for the observed damage symptoms

Insects were the predominant cause of damage and responsible for 27.8% of all recorded damage symptoms (Figure 7-4). More than half of the symptoms caused by insects were attributed to defoliators (52.4%), the most frequent of all specified damage causes. Leaf miners were responsible for 13.6% and wood borers for 13.3% of the damage caused by insects.

Abiotic agents were the second major causal agent group responsible for 15.1% of all damage symptoms. Within this agent group, half of the symptoms (49.0%) were attributed to drought, while wind caused 8.9% and frost 6.5% of the symptoms.

The third major identified cause of tree damage were fungi with 12.0% of all damage symptoms. Of those, 21.4% showed signs of canker, followed by decay and root rot fungi (17.9%), needle cast and needle rust fungi (16.1%), and powdery mildew (13.0%).

Direct action of man, including silvicultural operations and mechanical damage from vehicles, accounted for 5.1% of all recorded damage symptoms. The damaging agent group 'Game and grazing' was of minor importance (1.1%) and may be relevant only in certain areas. Fire caused 0.7% of all damage symptoms. The agent group 'Atmospheric pollutants' refers to local incidents mainly in connection with factories, power plants, etc. Visible symptoms of direct atmospheric pollution impact, however, were rare (0.03% of all damage symptoms). Other causal agents were responsible for 9.0% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable amount of symptoms (29.2%) could not be identified in the field.

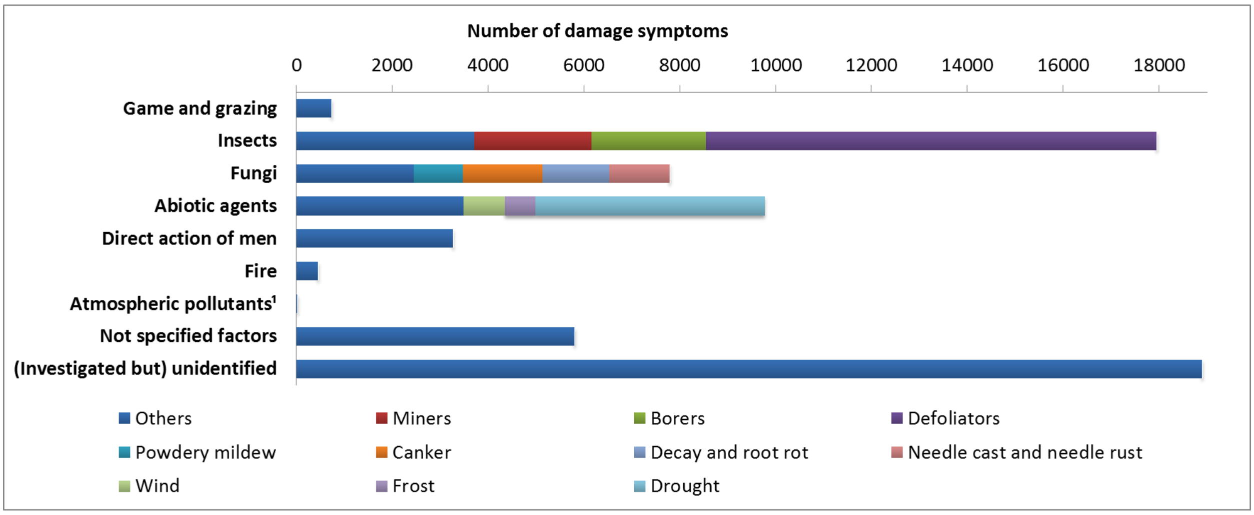


Figure 7-4: Damage symptoms according to agent group and specific agents/factors (n=64,630). Multiple damage symptoms on the same trees are included in the numbers. [1] Visible symptoms of direct atmospheric pollution impact only

The occurrence of damaging agent groups differed between major species or species groups. With the exception of Norway spruce and Scots pine, insects were the most prominent agent group (Figure 7-5). This holds especially for common beech (39.6%), deciduous temperate oaks (38.6%) and deciduous (sub-) Mediterranean oaks (32.7%). Abiotic factors caused by far most damage in evergreen oaks (43.8%) and Mediterranean lowland pines (41.4%). Fungi as damaging agents were most important in

Austrian pine (21.3%), deciduous temperate oaks (15.6%) and Scots pine (15.8%). Direct action of man had the highest impact on Norway spruce (13.7%) and Scots pine (8.6%). Damage from game and grazing played a minor role in all species and species groups except Norway spruce (9.3%). Fire affected mostly Mediterranean tree species. Scots pine and Austrian pine had a large share of damage symptoms caused by other factors. Out of those, the most prominent cause was mistletoe (*Viscum album*) with 31.4% of all reported other factors for Scots pine and 75% for Austrian pine. The percentage of recorded but unidentified damage symptoms was quite low in evergreen oaks (7.9%) and Mediterranean lowland pines (8.8%), but large for Norway spruce (43.6%), common beech (37.4%) and deciduous (sub-) Mediterranean oaks (36.5%).

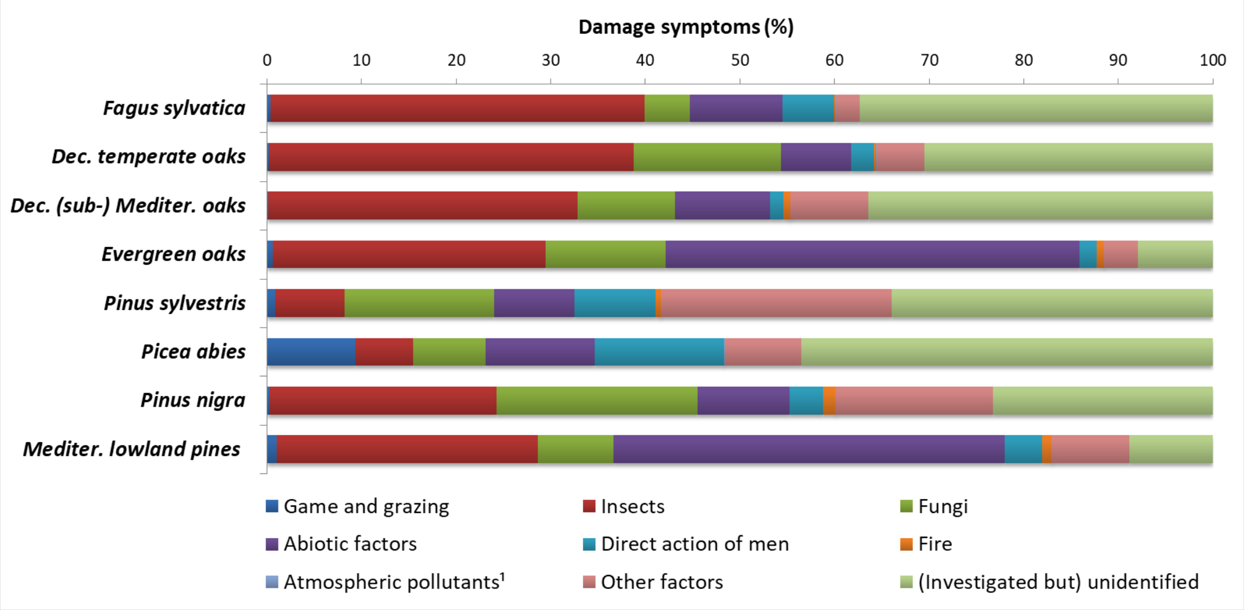


Figure 7-5: Damage symptoms according to agent group in the main tree species and species groups
[1] Visible symptoms of direct atmospheric pollution impact only

Regional importance of the different agent groups

In 2016, damage caused by insects was observed on 1,857 European Level I plots, which corresponds to more than one third (34%) of all plots with damage assessments. With a few exceptions (e.g. Sweden, Czechia), a high proportion of plots in each country was affected by this agent group, and also a high percentage of trees were damaged by insects on many plots throughout Europe.

Damage caused by abiotic agents was reported from 1,529 Level I plots (28%) throughout Europe. Since drought was responsible for almost half of these damage incidents, the most affected plots were found in Spain, southern France, Italy, Croatia, and Turkey.

The agent group 'Fungi' was responsible for damage on 1,304 European Level I plots (24%) in 2016 and was frequently occurring in most countries. Most of the plots with high percentages of damaged trees were reported from northern Norway, Belgium, France, and Bulgaria.

The damaging agent group 'Direct action of man' refers mainly to impacts of silvicultural operations, mechanical/vehicle damage, forest harvesting or resin tapping. This agent group impacted trees on 963 plots (18%) distributed throughout Europe. On 86.5 % of the plots, 25% or less of the trees were damaged by this agent group.

Damage caused by game and grazing was frequently observed in the Baltic States. Otherwise incidents were scattered throughout Europe, and in most cases only a few trees on each plot were affected. In total, 254 Level I plots (5%) had trees damaged by this agent group, with deer being responsible for 78% of all damage in this group.

Fires were reported from 52 Level I plots (1%) in Europe in 2016, most of them located in Spain. A few severe fires affecting more than 75% of the trees on a plot were reported from Hungary, Montenegro, Italy and Spain; otherwise in most cases less than 25% of the trees on a plot were damaged.

For maps showing incidents of various agent groups, please refer to the online supplementary material[1].

7.4 Conclusions

In 2016, the average crown defoliation in the participating countries was 22.1% for broadleaved and 20.1% for conifer species. For most species, it remained largely in the range of observations from previous years.

The defoliation of Scots pine, which generally does not deviate much from the trend, was higher in 2016 than the long-term mean, and the defoliation of Norway spruce remained on the level above the long-term trend for the third consecutive year. For Norway spruce especially, a large share of damage symptoms could not be assigned to specific damage agents, complicating the interpretation of defoliation assessments.

After several years of improved crown condition, the defoliation of beech increased to the highest value ever recorded. The most common identified causes of damage on beech in 2016 were mining insects and defoliators.

Mediterranean lowland pines showed the strongest trend in defoliation (around 3% every 10 years) while the highest mean defoliation in 2016 was observed in evergreen oaks (25.0%).

The average number of recorded damage symptoms per assessed tree was lower for the conifer species or species groups (on average 0.5 symptoms per tree in Norway spruce, Austrian pine, Mediterranean lowland pines and Scots pine) than for broadleaved species (on average 0.9 symptoms per tree in common beech, deciduous (sub-) Mediterranean and temperate oaks and evergreen oaks). Insects, abiotic causes and fungi were the most common damage agent groups, comprising altogether more than half (54.9%) of all damage records.

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8 SELECTED METEOROLOGICAL STRESS INDICES FOR 2013–2015

Anne-Katrin Prescher, Peter Waldner, Stephan Raspe[1]

8.1 Introduction

Climatic conditions significantly affect forest ecosystems and the inherent biogeochemical processes and relationships in the system of soil, plant and atmosphere. Major meteorological variables are air temperature, precipitation and wind speed next to radiation and air humidity. In forest ecosystems, temperature affects most biogeochemical processes, as photosynthesis and respiration, microbial activity and evapotranspiration. Precipitation influences water supply for plants and microbes, state of soil aeration, nutrient leaching as well as wet deposition.

In comparison to long-term means, annual weather conditions can vary significantly including extreme weather events. Different research showed that climate change towards higher mean and extreme temperatures and changing precipitation patterns will have severe effects on forest ecosystems due to direct effects as heat and drought stress, but also due to indirect effects as higher vulnerability to pests and diseases (Jentsch and Beierkuhnlein 2008; Lindner et al. 2010; Fettig et al. 2013). Furthermore, frequency of extreme events are expected to have a bigger impact on forest ecosystems than long-term means of climatic variables, especially if extreme events follow or overlap each other (Jentsch and Beierkuhnlein 2008; Lindner et al. 2010). Corcobado et al. (2014) found that drought had a larger effect on seedlings than water logging potentially effecting natural regrowth. The review of Allen et al. (2010) demonstrates that there is a high potential of increasing tree mortality due to prolonged drought periods and heat waves. Temperature extremes, precipitation extremes and wind throw have been again pointed out recently as the most important climatic and atmospheric stressors for forest health under global change (Trumbore et al. 2015).

In a changing climate, the observation and analysis of long-term climatic conditions and solely weather events is crucial to evaluate and rank the processes and changes observed in the different surveys of the ICP Forests monitoring program. Forest response, such as stress for trees due to specific weather conditions, depends on the temporal pattern of such events. Raspe (2001) reviewed meteorological stress indicators suggested and often used in literature (c.f. Raspe et al. 2016).

The objective of this preliminary study was to calculate values of stress indicators related to specific weather conditions across Europe of the years 2013 to 2015 and to identify potential spatial patterns and relationships for such weather events. For this purpose we selected stress indicators that explicitly do not take into account site and stand characteristics, i.e. did not consider variables such as potential evapotranspiration and available soil water capacity.

8.2 Methods

Within the framework of ICP Forests, meteorological measurements are continuously taken within the forest and/or on an open field in proximity of the Level II plots according to national methods following the harmonized methods described in the ICP Forests Manual (Raspe et al. 2016). These include a wide

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[1] For contact information, please refer to the annex.

range of meteorological variables aggregated on a daily basis to determine the climatic conditions of forests and to relate these to biogeochemical processes assessed in the other surveys of the ICP Forests monitoring program. In addition, in many countries, data from closest national weather stations are gathered as well.

For each Level II plot, data of air temperature and precipitation were compiled and used to calculate variables (stress indicators) that potentially indicate weather conditions related with potential stresses to the forest ecosystems (Table 8-1). Temperature related stress indicators *TropicalDays* and *IceDays* followed the definitions given in Raspe et al. (2016), Annex 4. The stress indicators related to precipitation, *MaxRain5* and *HeavyRainDays*, follow the definitions given in the Monitoring Report 2015 of the German Environment Agency (Umweltbundesamt 2015). To estimate a possible drought stress without the availability of soil water capacity values, we defined the indicator *NoRainPeriod*. However, the latter does not allow a judgement on actual drought stress, but defines the longest period without rain which, depending on site and stand characteristics, may cause eventually stressing dry or drought conditions.

The current analysis covers the study period 2013 - 2015 and is based on the current dataset of the ICP Forest database (April 2017). Only open-field measurements were considered, including data from plot associated weather stations. The meteorological data was checked for plausibility according to the ICP Forests Manual (Raspe et al. 2016) and was checked for completeness according to the following criteria: 1, a minimum of 350 measurement days per calendar year; 2, a minimum of annual mean daily measurement completeness of 95%, when stated. To allow comparability between the plots in conjunction to not discarding too many plots, measurements were filtered according to their measurement height above ground allowing the following ranges:

- Air temperature: between 1 m and 2 m (with the exception of 7 m in Spain)
- Precipitation: between 1 m and 2 m (with the exception of 4 m in Cyprus).

Only plots that have sufficient data for the three study years 2013, 2014 and 2015 were considered in this study. Since gap filling was not part of this analysis, these strict criteria reduced the number of plots considered in this study significantly. It should be pointed out that in general meteorological measurements are available for most Level II plots.

According to the description given in Table 8-1, the five stress indicator variables were calculated per year and plot. These annual values were then aggregated calculating mean *m* and standard deviation *sd* per plot for the study period 2013 – 2015. The year to year variability *cv* [%] was calculated with *cv* = 100* *sd*/*m*. Finally, a linear regression analysis between the mean values of the different variables and three plot location variables (latitude, longitude, altitude) was performed on an individual basis and on a multivariate basis. The associated regression coefficient R^2 was determined.

Table 8-1: Definition and abbreviation of stress indicators

Related to	Variable	Description
Temperature	TropicalDays	Days with a maximum daily air temperature of more than 30 °C
	IceDays	Days with a maximum daily air temperature of less than 0 °C
Precipitation	MaxRain5	The highest amount of precipitation within 5 days during winter (1st Jan – 28th Feb & 1st Oct – 31st Dec)
	HeavyRainDays	Days with a precipitation of more than 20 mm during vegetation period (1st May – 31st Aug)
	NoRainPeriod	Number of days of the longest period without rain (PR < 0.1 mm) during vegetation period (1st May – 31st Aug)

8.3 Results & Discussion

Annual variability of stress indicator variables across Europe

The inter-annual variability *cv* per plot varied between the stress indicator variables indicating different steadiness of the indicators within the years 2013 to 2015. For *TropicalDays* and *IceDays*, the interquartile ranges of *cv* were from 49% to 89% and from 41% to 80%, respectively. The interquartile ranges of *cv* for *MaxRain5*, *HeavyRainDays* and *NoRainPeriod* were determined to 22% to 45%, 35% to 88% and 24% to 53%, respectively. These results indicate that the year-to-year variability of the precipitation related indicators was in average lower than the ones of the temperature related stress indicators. From this, one may hypothesize that the precipitation related stress indicators are more stable and show fewer extremes at one plot. However, this result might strongly vary looking at the specific plots.

The annual variability of statistical variables of stress indicators is given in Figure 8-1. In general, the values of all stress indicators are skewed right in the three study years meaning that the bulk of values are in the lower range of the values margin. Further, it shows that there is a higher variance towards large values than towards small values. This picture is also influenced by the distribution of plots in this study comprising many plots in Central Europe and fewer plots in Northern or South Europe. However, the considered plots stay the same for all three years allowing an inter-annual comparison of the different stress indicators.

Due to the differences in absolute values, but also due to the ranges, annual differences can be observed. In 2015, the values of *TropicalDays* show a much larger range and a higher median than 2013 and 2014 implying that more plots across Europe showed higher temperatures than the years before. In 2015, 50% of the plots range between 4.5 and 30 *TropicalDays*, whereas in 2014, 50% of the plots range between 0 and 10.5 *TropicalDays* only. Also the comparison of mean values implies hotter conditions in 2015 than 2013 and 2014 with 20.3 versus 11.5 and 7.2 *TropicalDays*, respectively. Consequently, in 2015 more forest ecosystem were potentially affected by heat stress.

Regarding the amount of *IceDays* per year and plot, 2013 was found to be the year with the largest range and highest median showing that colder conditions were found at the considered plots. 50% of the plots range from 19 to 56.5 *IceDays* in 2013, but from 4 to 24.5 *IceDays* in 2014 and from 4.5 to 32 *IceDays* in 2015. Associated mean values are determined to 41.5, 23.2 and 21.5 *IceDays* in 2013, 2014 and 2015, respectively. Here, the time of the year when *IceDays* occur is crucial. *IceDays* in the vegetation period of trees can have severe impact and damage on tree growth, especially in deciduous forests. However, the potential that forests were endangered to frost stress was higher in 2013 than in the other years.

Next to temperature, the stress indicator variables related to precipitation can have a severe impact on the forest ecosystem. High amounts in precipitation can cause flooding or water logging, whereas low or no precipitation can lead to water deficit and drought stress. Here, two variables indicating the maximum amount of precipitation within five days during the winter months (*MaxRain5*) and the number of days with a precipitation sum of more than 20 mm during the vegetation period (*HeavyRainDays*) have been determined representing the potential for flooding, water logging and erosion. In contrast, the third variable *NoRainPeriod* is the number of days of the longest period without rain ($PR < 0.1$ mm) during vegetation period.

The maximum amount of precipitation within 5 days during winter (*MaxRain5*) was similar in the three years with slightly higher values in 2013. Median values of *MaxRain5 were* 39.5mm, 33.8mm and 38.2mm and mean values 58.8mm, 42.7mm and 51.4mm in 2013, 2014 and 2015, respectively. *HeavyRainDays* showed higher inter-annual differences with lower values in 2015 than in 2013 and

2014. Median values were determined to 4, 4 and 2 *HeavyRainDays*, whereas mean values reached 4.1, 4.7 and 2.8 *HeavyRainDays* in 2013, 2014 and 2015, respectively. Depending on the temporal distribution of these days with high precipitation and the actual precipitation sum at each day, the potential of flooding or waterlogging would be lower in 2015.

Averagely longer *NoRainPeriod* values were also found in 2013 with a median of 15 days and a mean value of 19.0 days in comparison to 2014 (median: 9; mean: 8.7) and 2015 (median: 11; mean: 13.9). In 50% of the plots, *NoRainPeriod* ranges between 11 and 21 days in 2013, but between 7 and 12 days in 2014 and between 9 and 15 days in 2015. Even that the potential of drought is higher with longer periods of no rain, no clear conclusion regarding the actual drought stress can be drawn since site and stand characteristics such as potential evapotranspiration and soil water capacity have to be considered for this.

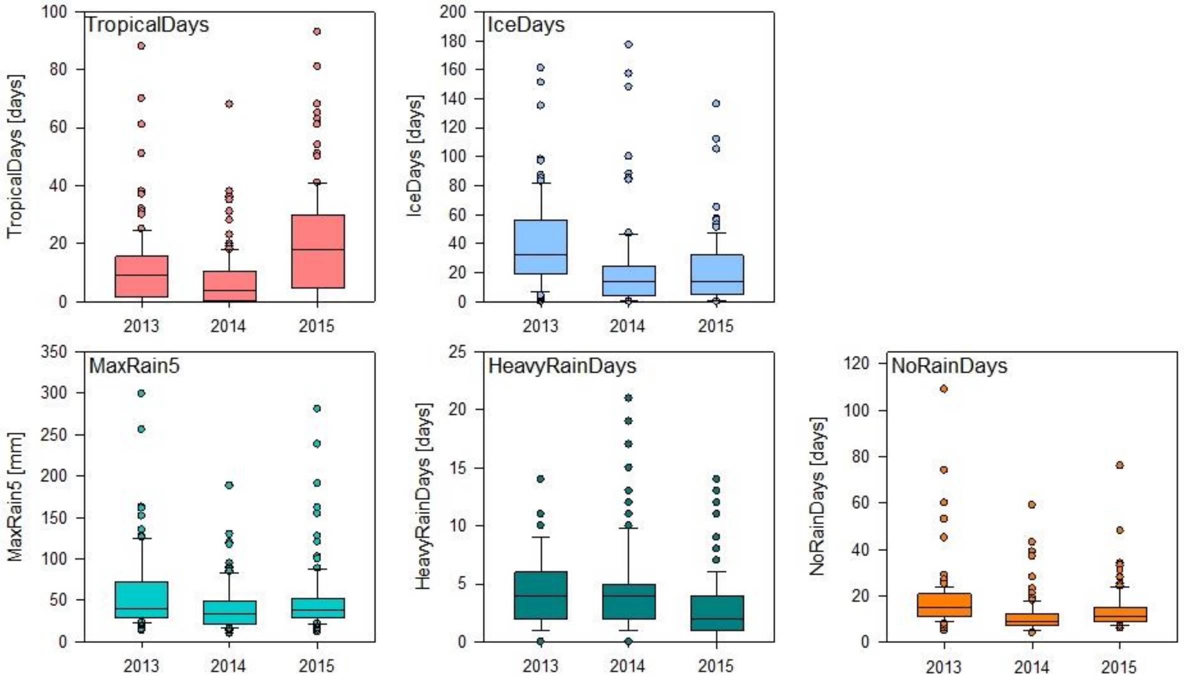

Figure 8-1: Indicators of meteorological stress in 2013, 2014 and 2015 across the considered European plots: 1, *TropicalDays* (Number of days with a maximum daily air temperature of more than 30 °C); 2, *IceDays* (Number of days with a maximum daily air temperature of less than 0 °C); 3, *MaxRain5* (The highest amount of precipitation within 5 days during winter); 4, *HeavyRainDays* (Days with a precipitation of more than 20 mm during vegetation period); and 5, *NoRainPeriod* (Number of days of the longest period without rain (PR < 0.1 mm) during vegetation period). Sample size for the indicators *TropicalDays* and *IceDays* is 108 plots and 97 plots for *MaxRain5*, *HeavyRainDays* and *NoRainDays.* (In the box plots, the box is limited at the lower end by the 25th percentile and at the upper end by the 75th percentile meaning that 50% of the values lie inside the box, but 25% of values below and 25% above the box. The bold horizontal line inside the box, whiskers and dots represent the median, the 10th percentile and 90th percentile, and outliers, respectively.)

Spatial variability of stress indicator variables across Europe

The mean values of the meteorological stress indicators (2013 – 2015) are mapped in Figure 8-2 to Figure 8-6 showing some distinct regional patterns. Across the considered plots, which are dominated by Central European sites, averagely 13.1 *TropicalDays*, 28.3 *IceDays*, 57.5mm of *MaxRain5*, 3.7 *HeavyRainDays* and a mean maximum *NoRainPeriod* of 15.8 days were determined for the study period of 2013 to 2015.

Regarding *TropicalDays*, 83% of the considered plots across Europe have a number below 20 days of which 20% are plots with no *TropicalDays* in the three years average. Especially, the plots situated in Northern Europe or in high mountain ranges (Alps, High Tatras, Carpathians, and Central System in Spain) feature only 0 to 5 days of *TropicalDays*, whereas Mediterranean or low land plots show in general values above 20 days. Even that these results implied it, testing the linear relationship between *TropicalDays* and latitude, and *TropicalDays* and altitude individually, only weak R^2 values of 0.164 and 0.110 were determined, respectively (Table 8-2). However, the multivariate linear model with latitude and altitude as variables reached an R^2 value of 0.475 meaning that ~48% of the variation in *TropicalDays* can be explained by latitude and altitude. Consequently, forests and forest vegetation in locations further South and lower altitudes have to cope with higher amounts of *TropicalDays* during the year. Adding longitude as additional explaining variable to the multivariate model increases the R^2 value only slightly demonstrating the low influence of longitude on *TropicalDays*.

The number of *IceDays* - days with a maximum air temperature of 0°C - was found lower in the Mediterranean region, but also close to coastal areas of the North Sea or Black Sea indicating the moderating effect of large water bodies for low temperatures. On the other side, plots in Scandinavia or the continental mountain ranges (e.g. Ore Mountains in Germany) show very high numbers of *IceDays* ranging from 50 to up to 158 days in Finland. In contrast to *TropicalDays*, the variable *IceDays* correlated well with latitude alone (R^2=0.606) and moderately with longitude alone (R^2=0.313). No individual linear relationship to altitude was found. However, the multiple linear model with latitude and longitude as variables resulted in a lower R^2 value (R^2=0.634) than the model with the explaining variables latitude and altitude (R^2=0.727). Including all three spatial variables, the multiple linear model explained 75.5% of the variation of *IceDays*. This implies that forests located further North-East in Europe in combination with higher elevation are more endangered to *IceDays*, frosts and frost damages. In Europe, North-East regions represent more continental climatic conditions including higher temperature ranges than regions in the South-West direction. However, the general principle of decreasing temperature with increasing altitude seems to have a stronger effect in combination with altitude.

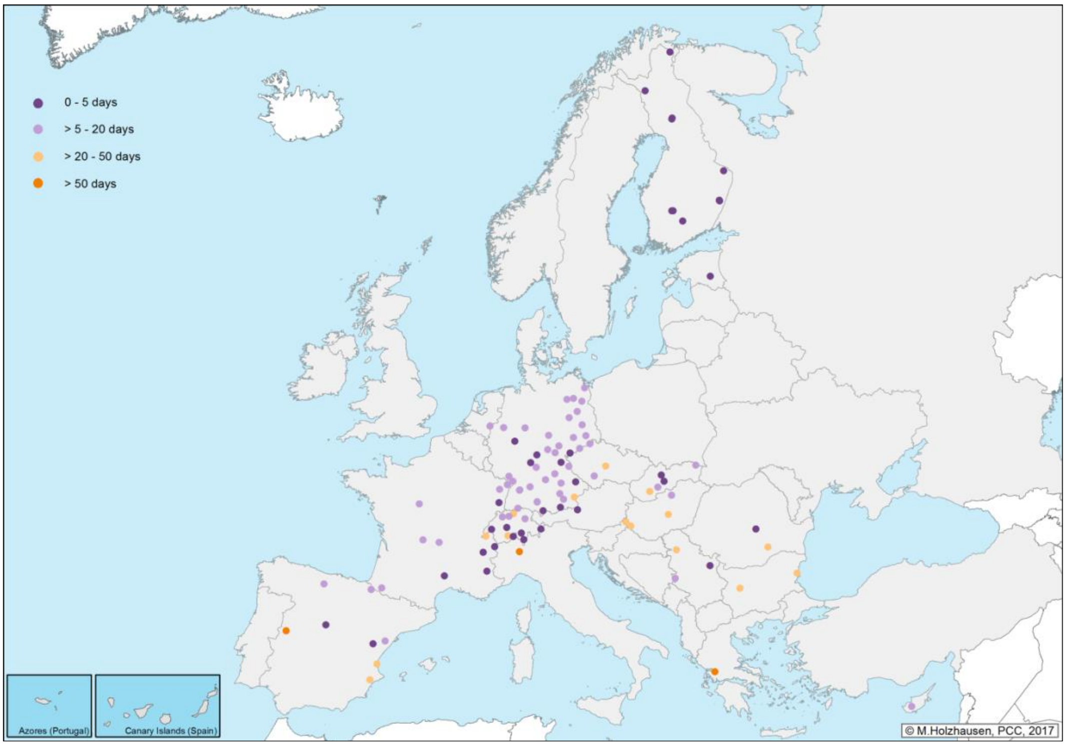

Figure 8-2: The stress indicator variable *TropicalDays* (Number of days with a maximum daily air temperature of more than 30 °C) across Europe. Average values (2013 – 2015) are plotted.

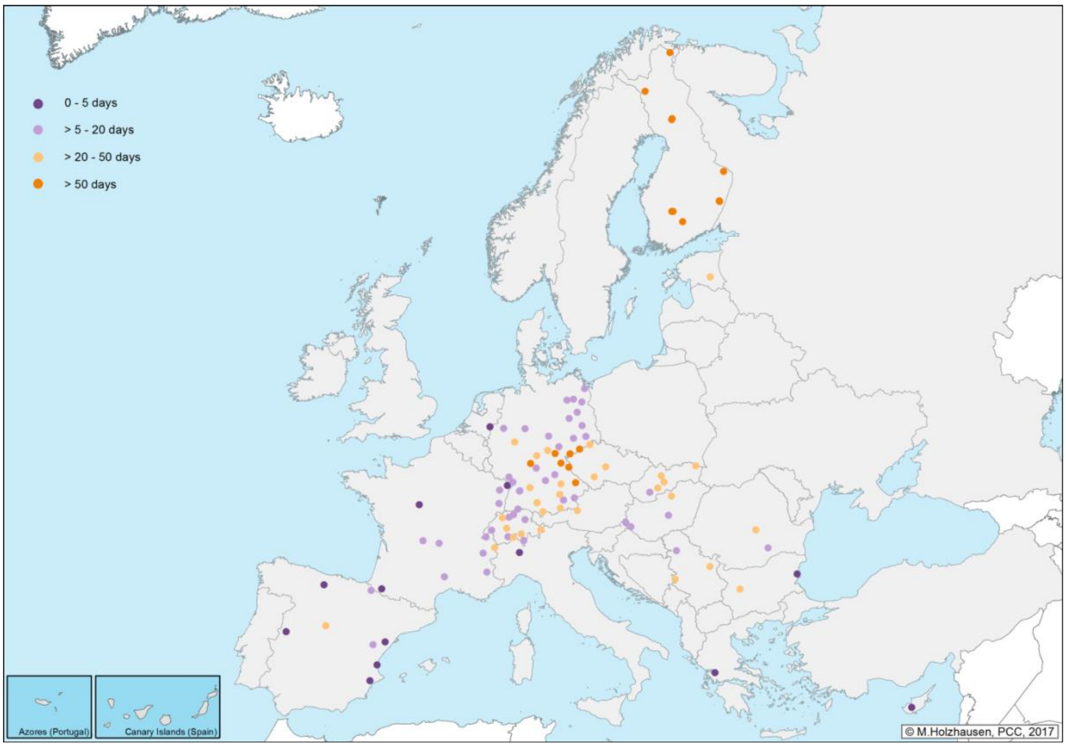

Figure 8-3: The stress indicator variable *IceDays* (Number of days with a maximum daily air temperature of less than 0 °C) across Europe. Average values (2013 – 2015) are plotted.

MaxRain5 was found to show a decrease from South-West to North-East Europe. In Spain, Southern France as well as Greece *MaxRain5* show very high values up to averagely 227 mm at one plot in Spain. The lowest average value in *MaxRain5* of 15 mm was observed in Northern Finland. This implies the impact of the Westerlies in the middle latitudes bringing wet air from the Atlantic to the European coast. Further, the higher winter temperatures in the South can lead to higher precipitation since warm air can store more water molecules consequently supporting the development of clouds and rain. The three individual linear regression analyses result in R^2 values of 0.248 for *MaxRain5* and latitude, 0.073 for *MaxRain5* and longitude and 0.151 for *MaxRain5* and altitude. The multivariate linear models increase R^2 values only slightly up to 0.290 in the model considering latitude, longitude and altitude. This low value implies that the occurrence of high *MaxRain5* is driven by other variables.

In contrast to the heavy precipitation sum in winter, during the summer vegetation period the stress indicator *HeavyRainDays* was found to be more diverse across Europe. 76% of the considered plots show 0 and 4 *HeavyRainDays* and the highest value averagely 14 days in the German Alps. Higher values seem to occur in the mountainous areas of the Alps, Pyrenees and German Ore Mountains, whereas the coastal parts of Greece, Cyprus and Denmark show lower values. However, the individual linear relationships between *HeavyRainDays* and latitude, longitude and altitude are very low, but showing the best fit between *HeavyRainDays* and altitude (R^2=0.177). As for *MaxRain5*, the multivariate linear model with all three location variables results in the highest, but weak R^2 value of 0.219 only. As similarly mentioned above, other variables seem to drive the number of *HeavyRainDays.*

The stress indicator *NoRainPeriod* was found highest in the Mediterranean countries with values higher than 20 days and lower in Central and Northern Europe, where especially the plots in the Alpine region showed only a *NoRainPeriod* of up to 10 days. 74% of the considered plots have an average *NoRainPeriod* between 10 and 20 days. Depending on the soil characteristics and the evapotranspiration of the forest ecosystem, forests at these plots seem to be not highly endangered to drought conditions.

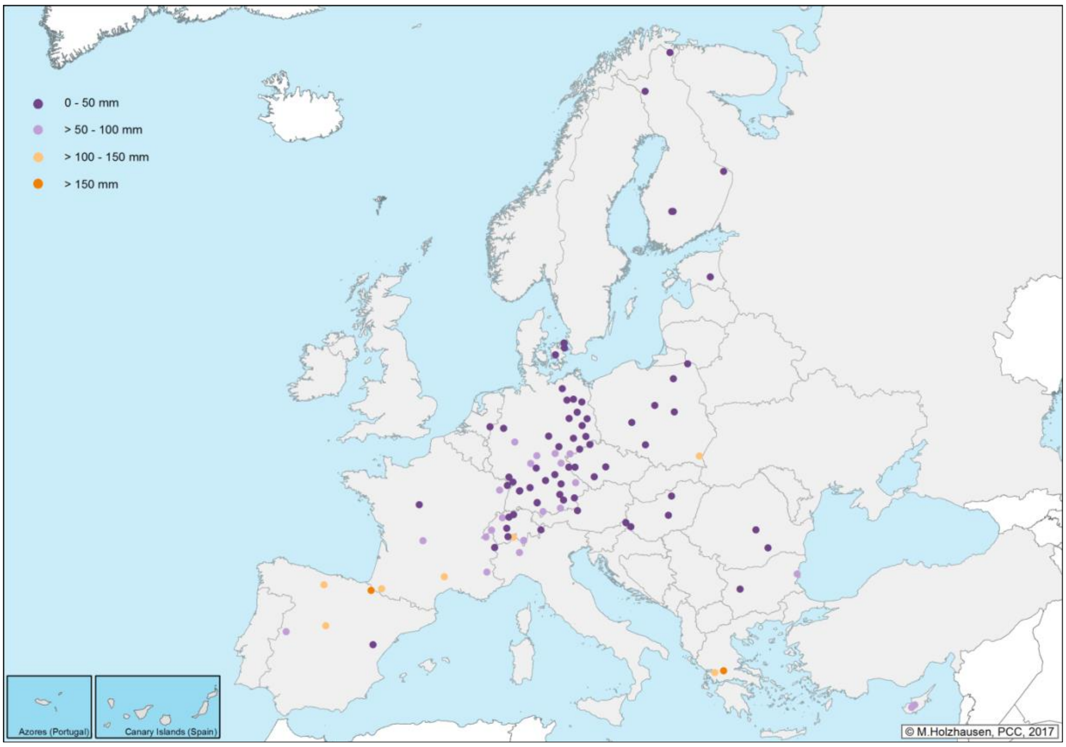

Figure 8-4: The stress indicator variable *MaxRain5* (Highest amount of precipitation within 5 days during winter) across Europe. Average values (2013 – 2015) are plotted.

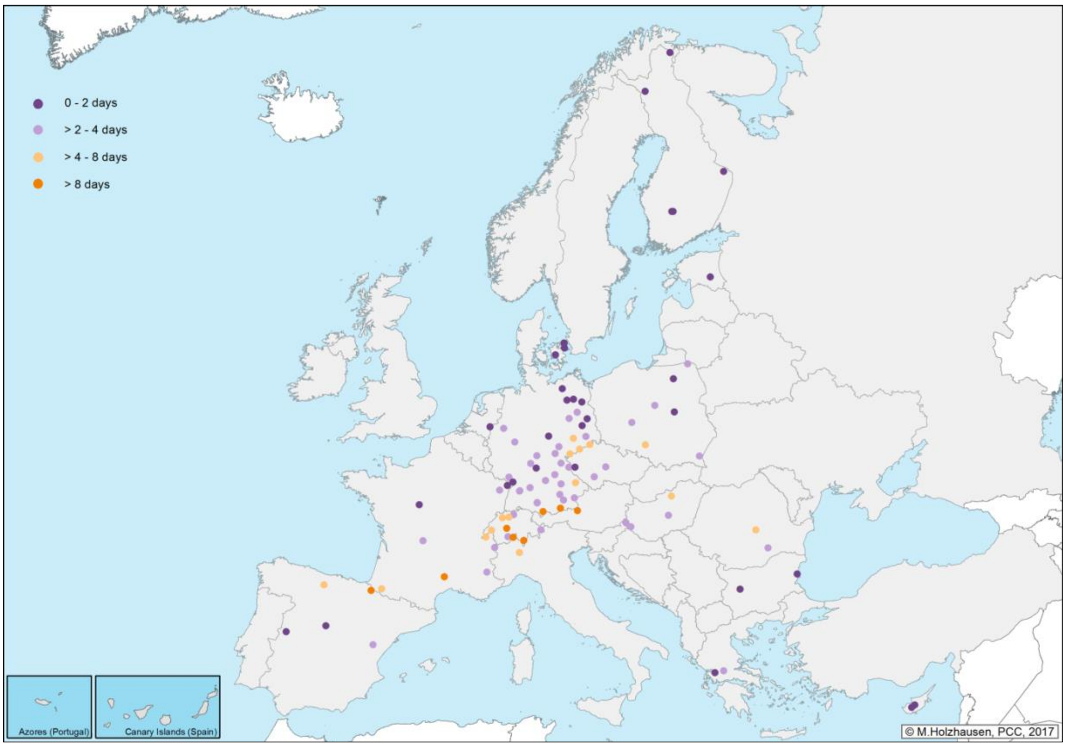

Figure 8-5: The stress indicator variable *HeavyRainDays* (Number of days with a precipitation of more than 20 mm during vegetation period) across Europe. Average values (2013 – 2015) are plotted.

However, the longest average *NoRainPeriod* of 72 days was observed in Cyprus, where the forest ecosystem had to adapt to such dry conditions. Regarding the linear regression models with one individual location variable, *NoRainPeriod* was highest, but still weakly, correlated to latitude ($R^2=0.267$). The R^2 value of this model could be improved by including longitude as a variable resulting in a R^2 of 0.361. Altitude had only very small effect on the correlation implying that there is no influence of altitude on the length of *NoRainPeriod.* This result is in contrast to the principle that precipitation usually increases with increasing altitude which might result from the Central Europe dominated considered plots.

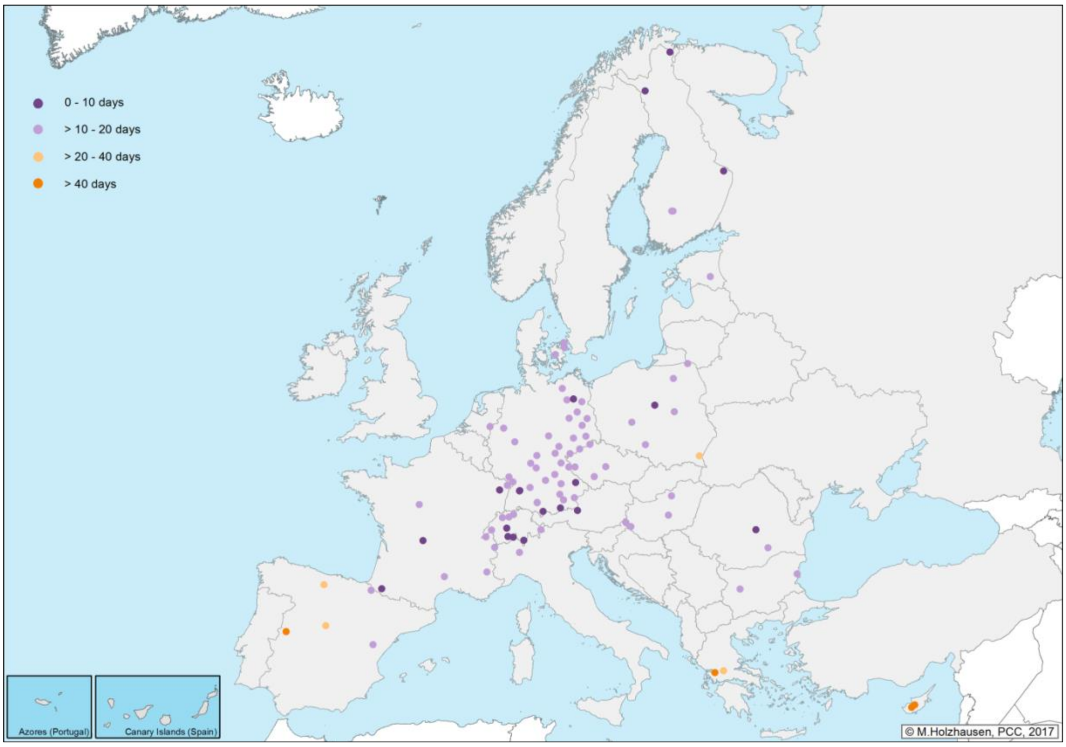

Figure 8-6: The stress indicator variable *NoRainPeriod* (Number of days of the longest period without rain (PR < 0.1 mm) during vegetation period) across Europe. Average values (2013 – 2015) are plotted.

Table 8-2: R^2 values of a simple linear regression between stress indicators and location parameters based on mean values (2013 – 2015). The sample size n represents the number of considered European plots for each calculation.

	T_{mean}	TropicalDays	IceDays	P_{mean}	MaxRain5	HeavyRainDays	NoRainPeriod
Latitude (Lat)	**0.453**	**0.164**	**0.606**	0.151	**0.248**	0.059	**0.262**
Longitude (Long)	0.146	0.015	0.313	0.166	0.073	0.082	0.021
Altitude (Alt)	0.051	0.110	0.000	**0.210**	0.151	**0.177**	0.021
Lat + Long	0.453	0.453	0.634	0.243	0.264	0.109	**0.361**
Lat + Alt	**0.776**	**0.475**	**0.727**	**0.247**	**0.277**	**0.180**	0.275
Lat + Long + Alt	0.777	0.488	0.755	0.327	0.290	0.219	0.369
n	*108*	*108*	*108*	*97*	*97*	*97*	*97*

8.4 Conclusion

Regarding the considered plots in this study, most stress indicators showed an inter-annual variability between the years 2013 to 2015. 2013 featured the plots with the highest number in *IceDays* in the study period implying colder conditions in that year. Since 2013 also featured slightly higher values in *MaxRain5*, larger range and values between the lower and upper quartile of plots in *HeavyRainDays,* and higher numbers in *NoRainPeriod*, the stress indicators suggest that 2013 was in average characterised by a mixture of strong precipitation in winter and dry periods in summer. The year 2014 showed low (*TropicalDays*, *IceDays*, *MaxRain5*, *NoRainPeriod*) or average (*HeavyRainDays*) values in the stress indicator variables indicating less extreme weather conditions in that year. 2015 was characterised by the highest values as well as the largest range between the lower and upper quartile of plots in the temperature stress indicator *TropicalDays* and by lower values in *HeavyRainDays*. However, despite the much higher numbers in *TropicalDays, NoRainPeriod* in 2015 lay in the average range implying a lower potential of drought. To draw general conclusions on the annual weather conditions, the seasonal distribution and average values of air temperature, precipitation, humidity, radiation and wind speeds have to be studied and cannot be estimated based on the used stress indicator variables. However, it could be shown that these stress indicators can significantly vary between years and that forest ecosystems needed to adapt on this variability.

Spatial variability was found in all stress indicator variables, but a strong correlation to specific location variables (latitude, longitude, altitude) was not always determined. However, looking at the linear models with just one location variable, four out of five stress indicators were strongest, even if weakly, correlated to latitude. Only *HeavyRainDays* showed a stronger correlation to altitude than to latitude. The multivariate linear models resulted in much higher R^2 values proving the high dependency of one location effect from a second or third location effect. *TropicalDays*, *IceDays*, *MainRain5* and *HeavyRainDays* were described best by a multivariate model with latitude and altitude as variables. The addition of longitude in these models increased R^2 only slightly, except for *HeavyRainDays*, underlining the different effects of longitude on these stress indicators. The stress indicators *NoRainPeriod* showed the best correlation to the multivariate linear model with latitude and longitude, in which the addition of altitude did not improve the R^2 value. The strongest correlation with a R^2 value of 0.755 was found between *IceDays* and a multivariate model with latitude, longitude and altitude. The temperature related stress indicators were much stronger correlated to latitude than the precipitation related indicators, especially in combination with altitude. This is due to the angle of incidence of solar radiation and due to the general decrease of temperature with height within the troposphere. Regarding linear regression models with one individual variable, the temperature related stress indicators were found to be much stronger correlated to latitude than to altitude. Franke et al. (2017) found a similar indication studying the growth of Scots pine along a latitudinal and altitudinal gradient in Finnish Lapland. Their results suggest that latitude had a larger effect on growth than altitude.

These results can have significant effects on forest ecosystem and tree growth. Even that *TropicalDays* were defined as the number of days with a maximum air temperature of 30°C and the limiting temperatures causing 50% damage to plants averagely just occur after a 30min treatment with 45°C to 50°C (Larcher 1994), tree growth response can be inhibited by reduced photosysthesis. Most tree species in Europe have a growth optimum below 30°C. If other stressors as drought or photoinhibition act additionally, high temperatures can already cause damages to the plants. But not only can the direct physiochemical effect of heat damage trees, but also the indirect effects by intensifying pests. Maximum air temperature sums of the previous year were found to increase the infestation of bark beetles in Norway spruce in the High Tatra National Park (Mezei et al. 2017). The intensity of damage on tree growth also depends on the duration of heat stress during the days. Song et al. (2014) found that in poplar photosynthesis completely recovered after 6 hours of heat stress (42°C), but recovery was restricted after 12 and 24 hours.

Regarding the effect of the precipitation related stress indicator on forest ecosystems, site conditions as soil water holding capacity, infiltration rates and evapotranspiration are crucial. Without this information, a judgement of the positive or negative effects is not possible. In general, the seasonal distribution of precipitation is important regarding their effect on forest growth. A study by Alma et al. (2014) for central Italian forest sites showed that at two sites Black pine growth was significant negatively correlated to precipitation in May whereas at one of these sites precipitation in June was positively correlated. In this study, the stress indicator *MaxRain5* was determined for December to February only, but *HeavyRainDays* is covering high precipitation from May to August. In winter, high precipitation is more likely to cause water logging and erosion since water is much less taken up by the plants than in summer and soil water status and infiltration rates are smaller. However, also heavy rain events in summer can cause erosion if infiltration is lower than the amount of rain. In addition, heavy rain can also cause direct physical damage to leaves depending on the tree species.

Looking at erosion aspects, but also at the other stresses to forests, local drivers as exposition and sheltering should also be considered in the analysis since they might have a high effect on plot related temperatures and runoff, and might buffer extreme values. In this study, open field measurements have been considered, that are in close proximity of the Level II plots, often situated within a forest glade. Thus, they represent the forest micro-climatic conditions or the conditions above the crown better than stations of the national weather services and allow a more appropriate estimation of the weather conditions that stress the forest ecosystem. We emphasise that the meteorological stress indicator values presented here do not take into account the site and stand characteristics on the Level II plots. These later influence the perception of stress by forest ecosystems since they potentially had time to adapt to site specific climate and soil conditions.

In this study, only data of the open field sites were considered. However, regarding the effects on understory and ground vegetation and the whole forest ecosystem, in stand climatic conditions should be considered since extreme conditions could be differently pronounced within the forest. Ferrez et al. (2011) studied extreme temperatures of open field and stand measurements during about 15 years on Level II plots in Switzerland finding that minimum temperatures are more dependent on location than maximum temperatures. However, the effects of extreme weather events on community productivity are controversial (Jentsch and Beierkuhnlein 2008). A next analysis should study longer periods to identify possible changes over time or trends. With such an analysis the potential risk of a certain forest ecosystem to increasing weather extremes can be judged.

This preliminary study concentrates on generally defined stress indicators most of them found in the literature. Due to the static definition of thresholds, as the 30°C threshold in *TropicalDays* or the 20mm threshold in *HeavyRainDays,* no conclusion can be drawn to site-specific extreme weather events. Extreme events can only be determined on basis of the long-term average climatic conditions for the specific site. This will be the next step in the identification of climatic stresses to forest ecosystems.

The results presented here show some characteristics and patterns regarding the selected stress indicators during the study period 2013 to 2015. Despite the short study period of this evaluation, substantial differences in the meteorological stress indicators values were found between plots across Europe. Therefore, it is crucial that climatic conditions have to be considered when evaluating the results of other surveys since significant differences in meteorological variables could indeed drive significant changes of the forest ecosystems.

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Part C

National reports of participating countries in ICP Forests

9 NATIONAL REPORTS OF ICP FORESTS PARTICIPATING COUNTRIES

All participating countries in ICP Forests this year were invited to submit summary reports on all of their ICP Forests activities instead of reports only on their 2016 national crown condition survey. Many countries have taken this opportunity to highlight recent developments and major achievements from their many national ICP Forests activities.

All written reports have been slightly edited primarily for consistency and are presented below. The responsibility for the national reports remains with the National Focal Centres and not with the ICP Forests Programme Co-ordinating Centre. For contact information of the National Focal Centres, please refer to the annex.

Andorra

National Focal Centre

Anna Moles and Silvia Ferrer, Ministeri de Turisme I Medi Ambient

Report on 2016 national crown condition survey

The assessment of crown condition in Andorra in 2016 was conducted on 12 plots in the national 4x4 km grid. The assessment included 288 trees, 119 *Pinus sylvestris*, 137 *Pinus uncinata*, 5 *Betula pendula* and 27 *Abies alba*, as in 2015.

Results for 2016 show that the forest condition has worsened compared to the improving tendency of the last years.

For all species, most of the trees were classified in defoliation and discolouration classes 0 and 1. The unfavourable climatic conditions in 2016, including low precipitation during the vegetative period, could explain the increasing defoliation and discolouration class 1 and decreasing class 0.

Related to defoliation, the large majority of trees of all species were classified in the no-defoliation class (value range from 68.3% to 100%). Only *Betula pendula* presented 100% of trees in defoliation class 0. This percentage was better than in 2015.

Results for discolouration were variable depending on the species. The majority of *Pinus sylvestris* (61.5%), *Pinus uncinata* (61.5%) and *Betula pendula* (60%) trees were classified mainly in the slight-discolouration class. The great part of trees of *Abies alba* were classified as not discoloured (74.0%).

The assessment of damage causes showed many causal agents, like wind, snow, falling trees, biological agents as fungus *Cronartium flaccidum* or the insect *Thaumetopoea pityocampa*, rots and lightning scars, which in total affected 11.1% of the sampled trees.

Belgium

Belgium/Flanders

National Focal Centre

Peter Roskams, Research Institute for Nature and Forest (INBO)

Main activities/developments

The Level I large-scale survey was conducted on the 4x4 km-grid. Crown condition assessments were performed on 71 plots, with 877 broadleaves and 704 conifers. The main tree species in the survey are *Pinus sylvestris* (n=523), *Quercus robur* (n=378), *Pinus nigra* subsp. *laricio* (n=171), *Fagus sylvatica* (n=117), *Q. rubra* (n=92) and *Populus* sp. (n=51). Other species are pooled in subsets with ‘other broadleaves’ or ‘other conifers’. A survey of ash dieback in Flanders was conducted in 2016 for the third consecutive year. A subsample of the Level I plots was included in this survey.

Level II monitoring activities were conducted in five plots. We participated in the NITRIPHYLL project (H2020) and collected samples of soil, soil solution, deposition and foliage in two Level II plots during the summer of 2016. We also participated in the ILTER TeaComposition project, a global litter decomposition study, and buried tea bags (green tea, rooibos) and local litter (leaves or needles) in five Level II plots in August 2016. Further steps were taken by the University of Antwerp in cooperation with INBO to upgrade the Level II plot in Brasschaat, which is equipped with a measuring tower for gaseous components, in order to meet the criteria of an ICOS Class-I-site.

Major results/highlights

In 2016, 20.3% of the Level I trees were in defoliation classes 2-4. The mean defoliation was 23.7%. A majority of the sample trees was classified in defoliation class 1 (71.0%). A maximum of 10% defoliation was assessed on 8.7% of the trees. The trees with more than 25% defoliation showed moderate (17.4%) or severe (2.4%) defoliation. The mortality rate was 0.5%. Defoliation scores were remarkably high in *Fagus sylvatica*. 41.9% of the trees showed more than 25% defoliation. The high defoliation score was related to mast fruiting. Seed production was observed on 94.9% of the trees. 52.1% of the trees revealed moderate to strong fructification. The share of trees with more than 25% defoliation was 18.8% in *Q. robur*, 21.6% in *Populus* sp. and 8.7% in *Q. rubra*. In the category ‘other broadleaves’ 33.9% of the trees were classified as being damaged. In several plots, a high level of damage was found in *Alnus glutinosa* and *Fraxinus excelsior*. Similar to previous surveys, *P. sylvestris* showed a better condition than *P. nigra*. The share of damaged trees amounted to 8.8% in *P. sylvestris* and 31.0% in *P. nigra*.

Biotic agents caused damage symptoms on several tree species. Damage due to defoliators was observed most frequently on *Q. robur*, with 9.0% of the trees showing severe insect damage (>10% defoliation). Several symptoms of fungal diseases were recorded. Known causes of discolouration of leaves or needles were *Scirrhia pini* (*Pinus nigra*), *Melampsora larici-populina* (*Populus* sp.), *Discula umbrinella* (*Fagus sylvatica*), *Cristulariella depraedens* (*Acer pseudoplatanus*) and *Microsphaera alphitoides* (*Q. robur)*. Dieback of shoots or branches is the most recorded symptom of *Hymenoscyphus fraxineus* (*Fraxinus excelsior*) and *Sphaeropsis sapinea* (*Pinus* sp.). *Phytophthora alni* caused damage in one alder plot (*Alnus glutinosa*).

A significant deterioration compared to the previous year was observed in *F. sylvatica* and the subsample with ‘other broadleaves’. Mean defoliation increased by 7.2 and 3.0 percentage points, respectively. Defoliation on *Q. robur* showed a significant decrease by 0.6 percentage points. Despite this slight improvement, the health status of *Q. robur* was weak in several plots. A non-significant change was registered in *P. sylvestris* (-0.4 percentage points) while *P. nigra* showed a significant improvement in crown condition (-2.0 percentage points).

A special survey on the condition of *Fraxinus excelsior* started in 2014. The common sample in 2014-2016 consisted of 252 trees. Ash dieback was shown to be widespread in Flanders, last year the disease was present in all of the plots surveyed. Mean defoliation increased every year, from 28.8% in 2014 and 34.3% in 2015 to 37.5% in 2016. The share of damaged trees was 32.1% in 2014, 47.6% in 2015 and 51.2% in 2016. 3.6% of the sample trees died since the start of the survey.

In Level II, recent evolutions in the N status were evaluated using long-term datasets on element ratios in soil solution and foliage. Changes in the chemical composition of the soil solution indicated an improvement in abiotic status, while biotic recovery appeared pending.

National publications/reports published with regard to ICP Forests data and/or plots

Cools N, Verstraeten A, Sioen G, Neirynck J, Roskams P, Louette G, Hoffmann M (2016) LTER-Belgium - Results of long-term, large-scale and intensive monitoring at the Flemish forest condition monitoring sites within the LTER-Belgium network. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2016 (INBO.R.2016.11433903). Instituut voor Natuur- en Bosonderzoek, Brussel. https://data.inbo.be/pureportal/files/12102554/Cools_etal_2016_LTERBelgiumResultsLongTermMon

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Verstraeten A, Verschelde P, De Vos B, Neirynck J, Cools N, Roskams P, Hens M, Louette G, Sleutel S, De Neve S (2016) Increasing trends of dissolved organic nitrogen (DON) in temperate forests under recovery from acidification in Flanders, Belgium. Sci Total Environ 553:107–119. http://dx.doi.org/10.1016/j.scitotenv.2016.02.060

Outlook

In the near future we are planning an analysis of the trends in the solid soil in the Level II plots in Flanders and a trend analysis of the concentrations in foliage. We will analyse samples of stem discs collected during thinnings in Level II plots in Flanders since 1987 in order to gain an insight into the nutrient uptake by the trees. The Level I crown condition assessments will be continued as well as the additional survey on the condition of *Fraxinus excelsior*.

Peter Roskams, Arne Verstraeten, Geert Sioen

Belgium/Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2016, the data were still collected in 8 plots for Level II/III and in 45 plots for Level I. Level I data were also included in the ICP Forest database.

Major results/highlights

This year seems to have been favorable to the oaks. They show a decrease in defoliation and there was virtually no chenille and powdery mildew attack.

The condition of the beeches is more worrying. The structure of their crown has been deteriorating for several years.

Douglas -fir expresses greater defoliation mainly due to the loss of needles caused by Swiss rust.

National publications/reports published with regard to ICP Forests data and/or plots

See our annual reporting on forest health (in French) which includes ICP Forest data on http://owsf.environnement.wallonie.be Data are also included in the Walloon Regional Environmental Report (in French) on http://etat.environnement.wallonie.be

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Croatia

National Focal Centre

Nenad Potočić, Croatian Forest Research Institute

Main activities/developments

NFC Croatia hosted the UNECE ICP Forests Combined Expert Panel Meeting, held 27-31 March 2017 in Zagreb.

Major results/highlights

Level I

Ninety-nine sample plots (2376 trees) on the 16 x 16 km grid network were included in the survey 2016 with 2037 broadleaved trees and 339 conifers.

The percentage of trees of all species within classes 2-4 in 2016 (28.5%) was somewhat smaller than in 2015 (29.7%) and 2014 (31.5%). The percentage of broadleaves in classes 2-4 (24.7%) was also somewhat smaller, and for conifers there was a major difference in 2016 (51.0%) in comparison with 55.9% in 2015, which is more in line with the results from previous years, 49.7% in 2014 and 48.3% in 2013.

While poor crown condition of black pine is more or less a constant (62.8% this year), also *Abies alba* with 64.2% trees in classes 2-4 remains one of our most defoliated tree species. The deterioration of crown condition of narrow-leaved ash is very dramatic: the percentage of trees in classes 2-4 increased from 23.6% in 2013, through 49.1% in 2014 and 62.5% in 2015 and 72.2 in 2016. Along with dry years, and the presence of *Stereonychus fraxini*, also the increased presence of *Hymenoschyphus fraxineus* (*Chalara fraxinea*) in the last few years seems to be a factor causing increased deterioration of ash health.

Damage caused by biotic and abiotic factors on Level I plots has been monitored since 2015. The largest number of damages was recorded on leaves, followed by branches, shoots and buds, and finally on the trunk and butt end. Most of forest tree damage is caused by insects (20.7% of all damage), especially defoliators (12.0%) and leaf miners (4.5%). Next are abiotic agents with 12.9% of all damage, the most significant agent being drought with 4.2%. Damage caused by fungi accounts for 6% of all damage, while direct human activity accounts for 4.8% of all damage to forest trees.

Level II

Annual defoliation values on our intensive monitoring plots primarily depend on local climate parameters, as well as on biotic and abiotic factors. For instance, damage from beech leaf-mining weevil (*Rhynchaenus fagi*) was recorded in 2016 on plot 103, pine processionary moth (*Thaumetopoea pityocampa*) damage on plot 111 in 2015 and 2016, and leaf chlorosis as the consequence of oak lace bug (*Corythuca arcuate*) attack on plot 109 in 2015 and 2016. These pathogenic insects are widespread in Croatia.

The input of nitrogen into our intensive monitoring plots is below critical values (15-20 kg/N ha^{-1} y^{-1} for broadleaved forests and 10-15 kg/N ha^{-1} y^{-1} for coniferous forests).

Symptoms suggesting oxidative stress caused by high ground-level ozone concentrations were found on *Ligustrum vulgare* on plot 108 (Poreč) in 2016.

National publications/reports published with regard to ICP Forests data and/or plots

Potočić N (2016) *30 years of UNECE – ICP Forests* / 30 godina Međunarodnog programa za procjenu i motrenje utjecaja zračnog onečišćenja na šume (UNECE – ICP Forests). Šumarski list 1-2: 69 -74

Potočić N, editor (2017) 30 Years of ICP Forests in Croatia. Radovi Izvanredno izdanje/*Supplement* 11, Jastrebarsko, 56 pp.

Outlook

Average crown defoliation in Croatia in the period from 1998 to 2016 has a positive trend. In the case of common beech and pedunculate oak the trend is positive for both species, but the increase in defoliation for beech is much faster than for oak. In Croatia beech has for many years been the least defoliated species, but in 2016 this position was taken over by oak. Although no significant trend was determined for silver fir, it has for many years been one of the most damaged species. The biggest changes were recorded in the case of narrow-leafed ash whose average defoliation has in the last three years greatly deviated from the trend, making narrow-leafed ash currently the most damaged tree species in Croatia.

In 2016 the project “Adaptive Capacity of Croatian Mediterranean Forests to Environmental Pressures“ was started, aiming to determine the spatio-temporal variability in the condition of forest ecosystems through the use of various indicators (increment, tree mineral nutrition, crown defoliation, multispectral satellite images), taking into account forest structure, soil characteristics (including risk of soil erosion) and climate influences. Our plan is to use the UNECE ICP Forests large-scale (Level I) plot network to utilize the existing data (crown condition) and to obtain new data on relevant indicators (tree nutrition, increment). The field data will be complemented by the analysis of data from various information sources such as the E-OBS gridded dataset based on ECA&D information, in order to determine the current adaptive capacity of Croatian Mediterranean forests to climate change and to model the adaptation of those forests to different climate change scenarios. The project is carried out by the Croatian Forest Research Institute in cooperation with the Institute for Adriatic Crops and Karst Reclamation and the Meteorological and Hydrological Service in the period from 2016 to 2018. The project is financed by the Ministry of Agriculture from the Green Tax Fund. The project is financed by the Ministry of Agriculture of the Republic of Croatia.

Cyprus

National Focal Centre

Andreas Christou, Ministry of Agriculture, Natural Resources and Environment, Research Section – Department of Forests

Report on 2016 national crown condition survey

The annual assessment of crown condition was conducted on 15 Level I plots, during the period September – October 2015. The assessment covered the main forest ecosystems of Cyprus and a total of 361 trees (*Pinus brutia, Pinus nigra* and *Cedrus brevifolia)* were assessed. Defoliation, discoloration and the damaging agents were recorded.

A comparison of the results of the conducted survey with those of the previous year (2015) shows a decrease of 14.2% in class 0 (not defoliated) and 8.2% in class 1 (moderately defoliated). An increase of 20.5% in class 2 (severely defoliated), a slight increase of 1.7% in class 3, and 0.3% in class 4 has been observed.

From the total number of trees assessed (361 trees), 15.5% of them were not defoliated, 49.6% were slightly defoliated, 31.9% were moderately defoliated, 2.8% were severely defoliated and 0.3% dead.

In the case of *Pinus brutia*, 13.3% of the sample trees showed no defoliation, 47.2% were slightly defoliated, 36.2% were moderately defoliated, 3.0% were severely defoliated and 0.3% were dead. For *Pinus nigra*, 30.6% of the sample trees showed no defoliation, 58.3% showed slight defoliation and 11.1% were moderately defoliated. For *Cedrus brevifolia*, 20.8% of the sample trees showed no defoliation, 66.7% were slightly defoliated, 8.3% were moderately defoliated and 4.2% were severely defoliated.

A discoloration has been observed as well. From the total number of trees assessed (360 trees), 66.9% of them was not discolorated and 33.1% was slightly discolorated.

From the total number of sample trees surveyed, 48.3% showed signs of insect attacks and 16.7% showed signs of attacks by "*Other agents*, *T8*" (lichens and dead branches). Also, 6.9% showed signs of both factors (insect attacks and other agents).

The major abiotic factors causing defoliation in some plots, during 2016, were the combination of the climatic with the edaphic conditions which resulted to secondary attacks by *Leucaspis* spp. and defoliator insects, to 1/2 of the trees.

Czechia

National Focal Centre

Bohumir Lomsky, Forestry and Game Management Research Institute (FGMRI)

Main activities/developments

The National Focal Centre organized a seminar entitled "Forest health and forest production in the dynamics of anthropogenic changes and natural conditions", which took place in the Giant Mountains in 2016. The seminar was attended by representatives of the Administration of Giant Mountains National

Park and our colleagues from NFC Slovakia. The subjects of expert discussions were the results of monitoring ICP Forests and their comparison between both countries.

Major results/highlights

Unfavorable development of climatic factors (extreme drought) during the growing season in 2015 predisposed forest stands to greater susceptibility to other, mainly biotic harmful factors, which showed itself in 2016. The favorable course of weather in spring 2016 did not prove to eliminate these negative consequences of the previous year. An increased occurrence of drying trees was recorded in most coniferous tree species, almost throughout the country, but especially in North Moravia, where weakened spruce stands were subsequently attacked by bark beetles. The relatively high occurrence of dry pine, among others, infested by various biotic pests in the middle and lower altitudes, especially in the Elbe lowland and the South Moravian valleys. From the point of view abiotic influences, the widespread hail damages were also reflected in southern Bohemia, which affected forest stands of all ages.

For coniferous species the most significant changes were observed for larch (*Larix decidua*), in the younger category (stands up to 59 years) there was an increased defoliation percentage in class 1 (> 10-25%) from 29.0% in 2015 to 43.5% in 2016, at a simultaneous decrease in class 0 (0-10%). In the older larch stands (stands older than 59 years) the defoliation percentage increased in class 2 (> 25-60%) from 67.8% in 2015 to 75.0% in 2016, at a simultaneous decrease in class 1. For older stands of fir (*Abies alba*) there was an increase in the defoliation percentage in class 3 (> 60-99%) from 0.0% in 2015 to 2.9% in 2016, at a simultaneous decrease in class 0. The defoliation trend of broadleaved species indicates an obviously worsening in younger stands of other broadleaves due to an increase in the defoliation percentage in class 2 from 34.9% in 2015 to 50.6% in 2016, at a simultaneous decrease in the percentage in class 0 and 1. In older oak stands (*Quercus* sp.) the defoliation percentage increased in class 2 from 59.8% in 2015 to 66.5% in 2016, at a simultaneous decrease in class 1. In older beech stands (*Fagus sylvatica*) there was a decrease in the defoliation percentage in class 0 from 34.6% in 2015 to 26.1% in 2016, at a simultaneous increase in classes 1 and 2. For all tree species increased mortality was recorded.

Outlook

The Czech Republic, respectively organizers of the ICC 2017, for fulfilling new ideas and requirements during the organization of the ICC decided to move the location of the ICC to South Moravia. In this region we can use for such purposes favorable transport accessibility, extensive forest stands of all basic European tree species as spruce, pine, beech, oak and birch. We will try to maintain the new locality for the organization of all future ICCs for comparability. New localities allow to compare chosen tree species at different site conditions e.g. drift sand, floodplain forest, mountain sites. That is why this location can be interesting for most European countries.

Denmark

National Focal Centre

Morten Ingerslev, Department of Geosciences and Natural Resource Management, University of Copenhagen

Main activities/developments

Installation of one new intensive Level II plot with Norway spruce (45-year-old in 2016) in Central Jutland. This plot is now fully instrumented and regular sampling frequencies are maintained. The new plot is named “Tyvkær” and has no. 101. This plot was established because our previous Norway spruce plot in this region of Denmark was storm felled two years before. Hence, plot no. 101 will in many aspects act as a substitute for plot no. 11.

We have made a national crown condition intercalibration course for the NFI teams inspired by the results of the 2015 Photo ICC.

We have engaged in the LTER network and have established LTER Denmark. Inger Kappel Schmidt and NFC/Denmark are coordinating the activities. In this context, we now have one Danish intensive Level II ICP Forests plot (Plot no. 85, “Vestskoven”, oak) accepted by ILTER.

Major results/highlights

The national crown condition survey showed a slight increase in defoliation for most species. However, the general forest health is satisfactory apart from ash (*Fraxinus excelsior*), which suffers from ash dieback. There are continued problems with oak in areas with high ground water levels and heavy clay soils.

National publications/reports published with regard to ICP Forests data and/or plots

Larsen HM, Callesen I, Jørgensen BB, Thomsen IM (2016) Påvirker ekstremnedbør sundheden i stilkeg? [*Does extreme precipitation influence the health of common oak?*] Skoven, 48(10):404-408

Nord-Larsen T et al. 2016. Skove og plantager (2015) [*Forest statistics 2015.*] Institut for Geovidenskab og Naturforvaltning, Københavns Universitet. ISBN 978-87-7903-751-9 http://static-curis.ku.dk/portal/files/166321316/Skove_og_plantager_2015_net.pdf

Outlook

As we have engaged in the LTER network, we will continue to engage more Danish intensive Level II ICP Forests plots in the ILTER network. In 2017 we will work on engaging plot 74, “Suserup” within LTER.

We are currently looking out for new ways of utilising the data and findings that are provided by the Danish ICP Forest plots, both within national and international research activities but also with regard to management guidelines and master student thesis activities. The long time series are very well suited for MSc thesis work, and this work can provide a good start for a scientific publication.

Estonia

National Focal Centre

Endla Asi, Estonian Environment Agency

Report on 2016 national crown condition survey

Forest condition in Estonia has been systematically monitored using Level I sample points since 1988.

The Level I forest monitoring network was used to assess the health status of 2,421 trees. 1,488 Scots pines (*Pinus sylvestris*), 584 Norway spruces (*Picea abies*) and 349 deciduous species, mainly Silver birches (*Betula pendula*) were assessed. The observation period lasted from July 12th to October 27th, 2016.

The total share of not defoliated trees, 49.9%, was 0.8% lower than in 2015. The share of not defoliated conifers, 51.3%, was higher than the share of not defoliated broadleaves, 41.5%, in 2016. The share of trees in classes 2 to 4, moderately defoliated to dead, was 6.4% in 2016 and 6.8% in 2015. The share of conifers and broadleaves in defoliation classes 2 to 4, moderately defoliated to dead, was 6.5% and 5.4% accordingly. A significant change of defoliation of broadleaves was observed.

Scots pine has traditionally been and remained the most defoliated tree species in Estonia. The share of not defoliated pines (defoliation class 0) was 51.7% in 2016, 2.4% higher than in 2015. The share of pines in classes 2 to 4, moderately defoliated to dead, was 5.4%, slightly lower than in 2015. However, the long-term trend of Scots pine defoliation since 2009 has improved. In 2009, the share of not defoliated pine trees was 38% and 51.7% in 2016.

Concerning Norway spruce some long-term increase of defoliation occurred. The share of not defoliated trees (defoliation class 0) was 63.7% in 2010 and 50.2% in 2016. The share of not defoliated trees was higher, 74%, in younger stands with the age up to 60 years and 29.8% in older stands.

The defoliation of Silver birches increased about 28.2% in the last two years, mainly caused by birch rust (pathogen *Melampsoridium betulinum*) and insects. The share of not defoliated silver birches was 48% in 2016, 53.9% in 2015 and 76.2% in 2014.

All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage. Numerous factors determine the condition of forests. Climatic factors, disease and insect damage as well as other natural factors have an impact on tree vitality.

In 2016, 7.3% of the trees observed, had some insect damages, 23% had symptoms of fungi (mainly Scots pines). Overall 30% of trees had no identificable symptoms of any disease.

Visible damage symptoms recorded on Scots pine were mainly attributed to pine shoot blight (pathogen *Gremmeniella abietina*). Symptoms of shoot blight were recorded on 22% of the observed pine trees in 2016, it was 43% in 2015. Norway spruces mostly suffered due to root rot (pathogen *Heterobasidion parviporum*) – characteristic symptoms of the disease were observed on 4.8% of sample trees.

No substantial storm damages and forest fires occurred in 2016.

Finland

National Focal Centre

Natural Resources Institute Finland (Luke), Finland
Päivi Merilä

Main activities/developments

The main ICP Forests activities in Finland included monitoring of deposition, soil solution and litterfall based on monthly samplings on 12 Level II plots. In addition, 14 Level II plots were monitored for crown condition and foliar chemistry and were sampled for soil condition monitoring. Phenology monitoring continued on two plots and automated increment bands gathered data on five plots. In spring 2017, two Level II plots located in Juupajoki are clearcut, but monitoring activities are continued on these plots.

Major results/highlights

We analysed the change in the cover percentage of 11 common boreal forest understorey species in Finland in 1985–2006 on 443 Level I plots (Tonteri et al. 2016). The plant species demonstrated contrasting responses to regeneration cuttings and thinnings in accordance with their light demands, which also accounted for the time required for a species to recover from cutting disturbance. Species-specific responses to cuttings revealed considerable differences within plant functional groups (e.g. dwarf shrubs, herbs, mosses). The results emphasized the dominant role of forest cuttings as a driving force of the vegetation changes in Finland, while only slight signals of the effects of climate warming were found in few species. The effect of nitrogen deposition remained unconfirmed. However, the potential enhancing effect of nitrogen deposition and warm growing seasons on tree growth, and thus indirectly on the conditions of understorey vegetation, cannot be ruled out.

National publications/reports published with regard to ICP Forests data and/or plots

The following scientific papers including Finnish ICP Forests data and/or contribution of our research group were published:

Vuorenmaa J et al. (Lindroos A-J, Ukonmaanaho L from Luke) (2017) Long-term sulphate and inorganic nitrogen mass balance budgets in European ICP Integrated Monitoring catchments (1990-2012). Ecological Indicators 76:15-29. https://doi.org/10.1016/j.ecolind.2016.12.040

Tonteri T, Salemaa M, Rautio P, Hallikainen V, Korpela L, Merilä P (2016) Forest management regulates temporal change in the cover of boreal plant species. Forest Ecology and Management 381:115-124. https://doi.org/10.1016/j.foreco.2016.09.015

Camino-Serrano M et al. (Nieminen TM from Luke) (2016) Trends in soil solution dissolved organic carbon (DOC) concentrations across European forests. Biogeosicences 13:5567-5585. doi:10.5194/bg-13-5567-2016

Nussbaumer A et al. (Rautio P, Ukonmaanaho L from Luke) (2016) Patterns of mast fruiting of common beech, sessile and common oak, Norway spruce and Scots pine in Central and Northern Europe. Forest Ecology and Management 363:237-251. https://doi.org/10.1016/j.foreco.2015.12.033

Lehtonen A et al. (Salemaa M, Nieminen TM from Luke) (2016) Forest soil carbon stock estimates in a nationwide inventory: evaluating performance of the ROMULv and Yasso07 models in Finland. Geoscientific Model Development 9:4169-4183. http://dx.doi.org/10.5194/gmd-9-4169-2016

Outlook

ICP Forests Level II programme is continued in Finland, but with reduced funding. The Level II data and sample plot network has proved a valuable research infrastructure in our country both nationally and internationally. A part of Finnish Level II plots are included in eLTER-research infrastructures.

France

National Focal Centre

Fabien Caroulle, Ministère de l’Agriculture, de l’Agroalimentaire et de la Forêt (Level I)
Manuel Nicolas, Office National des Forêts

Report on 2016 national crown condition survey

In 2016, the forest damage monitoring in the French part of the systematic European network comprised 10,885 trees on 543 plots.

Summer in 2016 was particularly hot and dry, especially during August. Due to this drought, and the one of the former year, all species, and especially broadleaves species, show an increase in their mean defoliation. Evergreen oak (*Quercus ilex*) and chestnut (*Castanea sativa*) are the species that suffer the most of foliage loss.

Death of sampled trees stayed at a relatively low level.

The number of discoloured trees was still low except for poplars, beech, wild cherry and Aleppo pine.

Damage was reported on about a quarter of the sampled trees, mainly on broad-leaved species. The most important causes of damage were mistletoe (*Viscum album*) on *Pinus sylvestris,* chestnut canker (*Cryphonectria parasitica*) and the oak buprestid (*Coroebus florentinus*) on *Quercus* spp. Abnormally small leaves were observed on different species, especially on *Quercus* spp. (mainly on evergreen and pubescent oaks).

Germany

National Focal Centre

Sigrid Strich, Federal Ministry of Food and Agriculture

Main activities/developments

Germany continued assessment at Level I and II. The data evaluation of the 2nd National Forest Soil Inventory (NFSI II) was finalised and the results were published as Thuenen Report no. 43.

Major results/highlights

Crown condition

In summer 2016, 28% of the forest area was classified as damaged (defoliation > 25% or damage classes 2 to 4), compared to 24% in 2015. 41% (2015: 43%) were in the warning stage and 31% (2015: 33%) showed no sign of defoliation. Mean crown defoliation increased from 20.0% to 21.2%.

Picea abies: the percentage of damage classes 2 to 4 increased from 28% to 31%. 34% (2015: 37%) of the trees were in the warning stage. The share of trees without defoliation was 35%, the same as in the previous year. However, mean crown defoliation increased from 20.6% to 21.0%.

Pinus sylvestris: In 2016 the share of damage classes 2 to 4 was 14% (2015: 13%). 51% were in the warning stage, the same as in the previous year. 35% (2015: 36%) showed no defoliation. Mean crown defoliation increased from 16.9% to 17.5%.

Fagus sylvatica: Crown condition of European Beech has declined since 2015. The share of trees in the damage classes 2 to 4 increased from 33% to 52%, and 36% (2015: 45%) are in the warning stage. The share showing no defoliation decreased to 12% (2015: 22%). Mean crown defoliation increased from 23.3% to 28.6%. Again abundant fruiting impacted crown condition with the frequency of mast years seemingly increased to every two or three years over last two decades. High summer temperatures in the year previous to the mast and abundant nitrogen nutrition are considered to be disposing factors. According to the results of the NFSI II, nitrogen concentrations in beech leaves indicate nitrogen excess nutrition on more than one quarter of the plots.

Quercus petraea and *Q. robur*: the share of damaged trees decreased by eight percentage points from 36% to 28%. Here we have seen a recovery since 2013. The share of trees in the warning stage was 48%

(2015: 40%). The share without defoliation was 24% and did not change compared to the previous year. Mean crown defoliation decreased from 24.1% to 21.4%.

Intensive monitoring

Sulfur and nitrogen deposition to the intensive forest monitoring sites decreased between 2004 and 2014. However, concentrations of inorganic nitrogen (N) in soil solution indicate that critical limits for nutrient nitrogen are still being exceeded on the majority of the plots. Analyses of the soil solid phase mirror the results of the NFSI. More detailed results are published under
http://blumwald.thuenen.de/level-ii/auswertungen/

National Forest Soil Inventory

Forest soil condition slowly recovers since the first national inventory (NFSI I) in the 1990s. The reduction of atmospheric deposition, particular of sulfur (S) and lead (Pb) are the main reason for this trend. In addition, liming of forest soils and the conversion of pure coniferous stands to deciduous and mixed stands had overall a positive effect. The evaluations of the NFSI are based on 1,900 plots. The field work of the NFSI II was carried out between 2006 and 2008 and the laboratory work between 2009 and 2010.

Topsoils partially recovered from acidification and depletion of base cations observed during the NFSI I. On average the acid-base status of the topsoil and the supply of nutrients improved. Especially limed plots and plots with deciduous trees show a clear recovery.

Critical loads for nutrient nitrogen were exceeded at 59% of the plots in 2007 (after 77% in 1990). Nitrogen stocks of all soil layers (up to 60 cm depth) decreased on average by annually 1% between NFSI I and NFSI II. Nutrition and the vegetation, however, still indicate excess N. In future the phosphorus (P) nutrition should receive more attention since P deficits were widely found in beech (60% of the plots) and oak (38%). Carbon stocks (organic layer and mineral soil up to 90 cm depth) amounted to 117 t ha^{-1}, of which 17% were stored in the organic layer and 58% in the topsoil. Thus, soils supply a bigger share to the C pool of forests than above-ground biomass. An annual increase in C stocks of 0.75 t ha^{-1} from NFSI I to NFSI II was observed. The heavy metal content showed a simultaneous translocation from the organic layer to the top soil, causing a depletion of heavy metals in the organic layer. The precautionary values for arsenic and Pb, however, are still exceeded at several plots.

The condition of the forest soil improved slowly but future measures should aim at reduction of soil acidification and pollutant input in order to prevent undesirable nutrient losses and to diminish stresses. Highest priority should be given to the mitigation of N deposition. Soil liming at plots sensitive to atmospheric acidification is further recommended.

National publications/reports published with regard to ICP Forests data and/or plots

Please refer to this page: http://blumwald.thuenen.de/level-ii/literatur/

Results of the NFSI, including an English summary and a large number of maps, are published here:
https://www.thuenen.de/de/wo/arbeitsbereiche/waldmonitoring/bodenzustandserhebung/

Outlook

Since 1 January 2014, yearly crown condition assessments on a 16 by 16 km grid and monitoring on intensive monitoring plots (Level II) are mandatory in Germany according to the federal regulation on the environmental monitoring of forests (Verordnung über Erhebungen zum forstlichen Umweltmonitoring - ForUmV). An expert group with experts from the Länder and federal institutions working under this regulation has identified 68 Level II plots which are necessary to cover national information needs. A regulation on a third National Forest Soil Inventory is being prepared, aiming to carry out the next survey in the 2020s.

Greece

National Focal Centre

Dr Panagiotis Michopoulos
Hellenic Agricultural Organization – DEMETER, Institute of Mediterranean Forest Ecosystems

Main activities/developments and major results/highlights

Level I plots

Crown condition assessment

For the year 2016, the crown assessment survey was carried out in 23 Level I plots in Greece. The total number of trees assessed was 539, whereas 258 of them were trees of broadleaved species and 281 were trees of coniferous species. Comparing the survey of the year 2016 with the last survey (2015), the Level I plots were fewer by 48.9% and the total trees assessed by 48.4%.

The following table shows the results of the crown condition assessment survey for all the assessed tree species, the conifers and the broadleaves species.

	All tree species	Conifer species	Broadleaf species
No defoliation	50.9%	31.7%	69.8%
Slight defoliation	33.3%	44.4%	23.3%
Moderate defoliation	11.2%	16.6%	6.2%
Severe defoliation	3.9%	7.3%	0.7%
Dead trees	0.7%	0.0%	0.0%

These figures are considered to represent a healthy tree condition. More specifically, a percentage of 84.2% was classified in the No and Slight defoliation classes for all tree species, 76.1% for the conifers and 93.1% for the broadleaves. The main symptoms assessed in the conifer species resulting needle losses were epiphytes, insect attacks and abiotic reasons, while the main symptoms assessed in the broadleaved species resulting foliage losses were insect attacks and abiotic reasons.

Level II plots

In Greece there are four Level II plots. Plot 1 having an evergreen broadleaved vegetation (mainly *Q. ilex*), plot 2 with deciduous oak (*Q. frainetto*), plot 3 with beech (*F. sylvatica*) and plot 4 with fir (*A. borisii regis*). Full scale activities take place in the plots 1 and 4.

Crown condition assessment (Level II plots)

The survey continued for the year 2015 in the four plots and 170 trees (34 conifer trees and 136 broadleaves). The results showed a slight worsening of the trees' health condition in comparison to last year's results (2014). More specifically, the percentages for the different classes of defoliation are depicted in the table below.

Species	Year	No defoliation	Slight defoliation	Moderate defoliation	Severe defoliation	Dead trees
Conifers	**2014**	47.1%	20.6%	23.5%	2.9%	5.9%
	2015	38.2%	23.5%	32.4%	2.9%	2.9%
Broadleaves	**2014**	48.5%	41.2%	7.4%	2.2%	0.7%
	2015	47.1%	35.3%	10.3%	4.4%	2.9%

For the conifers (*Abies* sp.), there was an increase of the *Choristoneura murinana* insect attacks, while for the broadleaves species abiotic reasons were the main cause for defoliation.

Meteorology

From the observation and assessment of meteorological data in the *maquis* and fir plots, the conclusion was that there were no deviations from past years with regard to mean annual air temperature and mean air relative humidity values. A remarkable observation was that in December 2015 there was not a single event of rain in plot 1, something that has not been recorded for the last 45 years.

Nutrient fluxes

Deposition

Deposition was collected and analyzed in plots 1 and 4. The main finding was that for K throughfall was particularly important in the fir plot as it yielded 45 kg ha^{-1} yr^{-1} compared with 30 kg ha^{-1} yr^{-1} for plot 1.

Litterfall

The fir was the species that gave by far the highest amount of nutrients in litterfall. This means that among the four species fir is the most nutrient demanding one. For example, in 2015 the total N amount returned to the forest floor through litterfall (foliar and non foliar) was 96 for the fir, 57 for the maquis, 47 for the oak, and 34 kg ha^{-1} for the beech plot.

Nutrient concentrations

In 2015 there was plant tissue collection and analysis for all the four plots. In comparison to the 2013 results, no significant changes were observed apart for Mg concentrations in both beech and oak tree leaves where a reduction was observed. More specifically, the Mg concentrations in beech and oak leaves were found to be 1.75 and 1.80 mg g^{-1}, whereas in 2013 the Mg concentrations had been found to be 2.35 and 2.20 mg g^{-1}, respectively. This is particularly important as both beech and oak thrive in acid soils and a reduction in Mg concentration should always be considered seriously.

Hungary

National Focal Centre

László Kolozs, National Food Chain Safety Office, Forestry Directorate

Report on 2016 national crown condition survey

In 2016 the crown condition survey – based on the 16x16 km grid – included 78 permanent plots in Hungary. The assessments were carried out between 15 July and 15 August. In total, defoliation of 1872 sample trees was assessed, of which 89.5% of all were broadleaves and 10.5% were conifers.

In the recent years the share of healthy and slightly defoliated trees – despite the annual fluctuations – was near 80% but in 2016 the health condition of the Hungarian forests showed decline.

Of all tree species, 33.8% were without visible damage symptoms. The proportion of the not defoliated trees has decreased comparing to 2015. The percentage of the slightly defoliated trees was 31.6%, and the percentage of all trees within defoliation classes 2-4 (moderately damaged, severally damaged and dead) was 34.6%. In Hungary the dead trees remain in the sample while they are standing, but the newly (in the surveyed year) died trees can be separated. The rate of died trees in 2016 was 0.5% of all trees. The mean defoliation increased from 20.5% to 25.3%.

The tree species suffering the most damage are *Pinus nigra* (93.8%), and *Pinus sylvestris* (44.8%*).* Within broadleaved trees, the deterioration of crown condition was most prominent in *Quercus robur* (42.3%*)* (the percentages show the rate of sample trees belonging to category 2-4). *Other oaks* had the lowest defoliation rates in classes 2-4 (17.4%). Negative alteration was observed in respect of the defoliation rates by most of the species.

Discoloration can rarely be observed in the Hungarian forests, 90.7% of living sample trees did not show any discoloration despite the droughty summer weather.

Altough the damages caused by insects and fungi were dominant in general, the rates of the damaging agents showed differences in proportions between the tree species.

In 2016, defoliating insects had the highest rate, 26.6% of all damages was caused by them. The mean damage was 8.5%. These symptoms occurred particularly on the following species: *other softwood* (48.2%) and *Pinus sylvestris* (41.4%).

The rate of assessed damage caused by fungi was 21.1%. Fungal damage was mostly assessed on stems and roots (54%), on needles and on leaves (20.3%), too. *Pinus nigra* (40%) suffered the most fungal damage. The mean damage value was 19.9%.

The rate of the damages with unknown origin was 14.7%. 13% of the assessed damage was abiotic in 2016, which was slightly less than the previous years'. The general intensity was 24.1%. Within the abiotic damage most important identifiable causes were frost (39.4%) and drought (26.8%) and appeared in the largest measure on *Quercus cerris* (30.6%), *Fagus sylvatica* (19.9%), *Robinia pseudoacacia* (14.3%) and *Populus sp*. (14.9%).

The rate of the damaging agent group direct action of man in 2016 was 9.8 % of all damages. Other biotic damages were 8.6%. The game damaging generally showed low frequency (4%) but it appeared the most on *Robinia pseudoacacia* (12.2%) and *Carpinus betulus* (9.6%). The fire damage was not really common in the inspected stands (2.2%).

Ireland

National Focal Centre

Thomas Cummins, University College Dublin
Jim Johnson, University College Dublin

Main activities/developments

- Continued monitoring of deposition (bulk precipitation, throughfall) at three Level II sites and re-establishment of soil solution collection and tensiometers at two of these sites.
- Establishment of soil moisture monitoring at two Level II sites; soil moisture loggers, soil temperature, and soil-water tension sensors.

National publications/reports published with regard to ICP Forests data and/or plots

Johnson J, T Cummins, J Aherne (2016) Critical loads and nitrogen availability under deposition and harvest scenarios for conifer forests in Irealand. Science of the Total Environment 541:319-328 · September 2016. Available at: http://dx.doi.org/10.1016/j.scitotenv.2015.08.140

Outlook

Monitoring is currently taking place under a project funded until 30 June 2017. No funding is in place to continue monitoring subsequently. We are discussing with Department of Agriculture, Forestry and Food.

Planned projects

- Use of ICP Forests deposition data along with EMEP data to assess temporal trends in deposition chemistry
- Application of mixed model to assess contribution of throughfall and humus water to soil water chemistry

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Italy

National Focal Centre

Giancarlo Papitto, Carabinieri Corps – Office for Studies and Projects

Main activities/developments

A LIFE project, named SMART4Action (Sustainable Monitoring and Reporting to Inform Forest- and Environmental Awareness and Protection. LIFE13 ENV/IT/000813) was performed to redesign forest monitoring and its information and reporting system in Italy. It is designed over the period September 2014-March 2018 and will attempt to ensure financial sustainability to forest monitoring, despite budget restrictions, whilst maintaining scientific reliability. The project has two main goals: (i) design a new system to reduce the current annual costs by 30%, while recognizing the importance of national and regional statistics on key variables linked to sustainable forest management and ecosystem services; and (ii) to improve communication with, and data transfer to, relevant stakeholders and citizens through a participatory process.

In the first two years of the project, we performed a comprehensive spending review, considering all the costs incurred in the past, the operational costs and the need of maintenance of the sampling and analytical equipment

A questionnaire was distributed to citizens, forest managers, administrators and researchers in order to understand their information needs.

The spatial and temporal coherence of the data was also evaluated in order to identify a minimum set of plots and analyses able to assure the information needs of the stakeholders.

The guidelines for data evaluation and the results of this exercise are available at the follo-wing URL: http://www.corpoforestale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/12160.

A test phase on six forest plots was also run in 2016, to verify the effects of possible changes in the procedures of sampling and analysis, such as the use of weekly sampling and monthly analysis for atmospheric deposition, different admissible methods for plant species surveys, or different pooling criteria for foliar tissue analysis.

To increase awareness about forest related issues and the importance of forest monitoring, within SMART4Action synthetic result sheets at regional scale were prepared and a number of local conferences were held in localities close to the sampling sites, involving stakeholders, citizens and students.

To obtain a larger visibility and availability of monitoring data, a webGIS of the forest monitoring data was developed (http://smart4action.ise.cnr.it) and informative interactive touchscreens were set up in the sampling localities.

Finally, to reach a larger audience and to improve the awareness of the importance of forests and of forest monitoring among the younger people, we developed smartphone applications to allow to obtain monitoring data in the field and to actively involve citizens in simple monitoring activities.

Major results/highlights

Depending on the objective and the desired accuracy, considerable costs reduction seems possible for forest health and biodiversity assessment (Level I network only). Less significant is the forest growth costs reduction potential.

The evaluation of the data and analyses provided by the project provided some information very relevant to (i) demonstrate the value of the monitoring programme and (ii) for the future design of the monitoring networks. As for the former, there is clear evidence that the Level I and Level II network can provide important information on status and trends of forest health, growth and plant diversity at different spatial scales, national and sub-national. It is worth noting that the above themes were rated important by the stakeholder consultations. Present status and significant improvement in forest health (measured by defoliation), the contribution of mature forests to carbon stocks, the plant species richness in Italian forests were of particular value and provide reference for future work. As for the latter, the reported status and trends provide reference against which reduction in sampling effort (in terms of time frequency and in terms of spatial density) can be evaluated.

The examination and statistical assessment of temporal trends depicting the chemical aspects of forest ecosystem evolution underlined the importance of the strong inter-annual variability of parameters, mainly driven by meteorological phenomena, but further compounded by complex responses of forest ecosystems, which also show internal change processes, such as ongoing species replacement. The decreasing trend in sulphate deposition was followed by a reduction in the leaching of base cations from soil and increases in soil solution pH were also detected in several cases, while no trend was found in nitrogen deposition. Another time trend compounding soil reactions was a diffuse and significant trend of reduction in base cation deposition, which naturally tends to slow down ecosystem response to decreasing acidifying load, by concomitantly reducing external contributions to ecosystem buffering capacity. Nitrogen was decreasing in several beech and spruce sites and sulphur was decreasing in most oak and spruce sites.

Among the studied parameters, sulphate deposition was the only one showing clear, regionalized, spatial trends, strongly influenced by the episodic deposition of Saharan dust.

Other sources of variability between sites were more linked to the specific character of the forest and soil system in each site. The most relevant examples include the much more intense cycling of base cations in *Quercus* sites, the differences in SO_4-S retention due to soil properties, the kind of response to decrease acidifying load, whether decrease in BC leaching or increase in soil solution pH, which appear to be influenced by the size and availability of the BC pool in each soil.

National publications/reports published with regard to ICP Forests data and/or plots

A national "fact sheet" (available at the following URL: http://www.corpoforestale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/6%252F9%252F5%252FD.778d34b678c5125ddcf8/P/BLOB%3AID%3D12431/E/pdf and a number of regional "fact sheets" were prepared in order to share monitoring results to professionals and the large public, with particular reference to the Sustainable Forest Management indicators.

Outlook

The SMART4action project will last up to March 2018, and in 2017 we plan to further develop dissemination activities, holding field courses close to the sampling areas to teach simple monitoring techniques to the public. We will also finish the design of the new monitoring network, on the basis of the findings of the project.

Latvia

National Focal Centre

Andis Lazdins – Leader of the Level 2 monitoring programme in Latvia
Ainars Lupikis, Andis Bardulis, Aldis Butlers, Toms Sarkanabols – Latvian State Forest Research Institute Silava

Main activities/developments

Crown condition assessment was done in the end of August and beginning of September in two of the three Level 2 monitoring plots.

Major results/highlights

There is no evidence of any threats or any significant changes to forest health in Level 2 monitoring plots during the last assessment. Average defoliation has decreased by 0.7%. This corresponds with the overall trend of changes in defoliation in Level 2 monitoring plots in Latvia. Average defoliation has gradually decreased since 2009. No considerable changes have been observed regarding other assessed parameters.

National publications/reports published with regard to ICP Forests data and/or plots

Annual report “First and second level assessment of impact of air pollution” for year 2016 will be published until April.

Outlook

- It is planned to improve data export and provide data continuity from meteorological towers during 2017 by providing remote data transfer from towers.
- In 2015 two new plots were established. Currently, no crown condition assessment and foliar analysis have been done in one of those plots. It is planned to do it for 2017.

Lithuania

National Focal Centre

Albertas Kasperavicius, Lithuania State Forest Survey Service

Report on 2016 national crown condition survey

In 2016 the forest condition survey was carried out on 1,006 sample plots from which 82 plots were on the transnational Level I grid and 924 plots on the National Forest Inventory grid. In total 5,896 sample trees representing 19 tree species were assessed. The main tree species assessed were *Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens, Populus tremula, Alnus glutinosa, Alnus incana, Fraxinus excelsior, Quercus robur.*

During one year the mean defoliation of all tree species slightly decreased up to 22.4% (22.9% in 2015). 13% of all sample trees were not defoliated (class 0), 66% were slightly defoliated and 21% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers slightly decreased up to 22.3% (23.1% in 2015) and slightly increased for broadleaves up to 22.7% (22.5% in 2015).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 40% of all sample trees annually. Mean defoliation of *Pinus sylvestris* slightly decreased up to 23.1% (23.8% in 2015), while in 2008-2015 there was observed a slightly increasing defoliation.

Populus tremula had the lowest mean defoliation and the lowest share of trees in defoliation classes 2-4 since 2006. Mean defoliation of *Populus tremula* was 19.1% (18.3% in 2015) and the proportion of trees in defoliation classes 2-4 was 9.5% comparing with 9.9% in 2015.

Fraxinus excelsior condition remained the worst between all observed tree species. This tree species had the highest defoliation since the year 2000. Mean defoliation increased to 42.5% (41.1% in 2015). The share of trees in defoliation classes 2-4 increased to 62% (54% in 2015).

26% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by abiotic agents (about 8%) in the period of 2011–2016. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (60%), *Alnus incana* (40%) and *Populus tremula* (38%), the lowest for *Betula* sp. (17%) and *Alnus glutinosa* (19%).

In general, the mean defoliation of all tree species has varied inconsiderably from 1997 to 2016 and the growing conditions of Lithuanian forests can be defined as relatively stable.

Republic of Moldova

National Focal Centre

Stefan Chitoroaga, Agency Moldsilva

Report on 2016 national crown condition survey

In 2016 the assessment of forest health was performed for a total of 14,345 trees (14,308 – broadleaved trees and 37 – coniferous trees). As a result of the negative effect of biotic and abiotic factors the trees in the defoliation classes “none” constituted only 35.4%. The drought and adverse climatic conditions during the vegetation period affected the health of the trees in the forests of the Republic of Moldova. In 2016, weak unhealthy trees (defoliation class 1 – “slight”) constituted 38.1%, moderately unhealthy trees (defoliation class 2 – “moderate”) 24.6% and the strong unhealthy and dead trees (defoliation classes 3-4 “severe-dead”) 1.9%. As opposed to 2015 the coniferous forests were more affected in 2016, such that the conifers trees in the defoliation classes “slight” and “dead” (classes 1-4) was 35.1%

compared to 39.0% in 2016. All monitored deciduous species (oaks, locust, beech, ash, poplar and others) framed in defoliation class 1-4 ranged from 57.8% to 85.7% and trees in defoliation class 2-4 ranged from 11.4% to 40.6%.

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

Norway is represented in six Expert Panels (Soil and Soil Solution, Foliage and Litterfall, Crown Condition and Damage Causes, Forest Growth, Biodiversity and Ground Vegetation, and Deposition), the Working Group QA/QC, and is holding the co-chair of the EP Crown Condition and Damage Causes.

Level I

In 2016, the Norwegian national forest monitoring was conducted on 2,595 observation plots on a systematic grid of 3 x 3 km in forested areas of the country. The plots are part of the National Forest Inventory (NFI), who also is responsible for crown condition assessments. Defoliation assessments were carried out on 10,865 trees (Norway spruce and Scots pine) on 1,900 plots, damage assessments on 19,348 trees (all species) on all plots. A national field calibration course with 25 participants from the NFI was arranged for the monitoring. 629 plots are part of the transnational ICP Forests Level I grid, and crown and damage data for 5,221 spruce and pine trees were reported to the ICP Forests database in 2016.

Level II

At our three Level II sites, the following surveys are conducted: Crown condition and damage causes, tree growth, foliar chemistry, ground vegetation, soil solution chemistry and atmospheric deposition. Chemical analyses are carried out in-house. Ambient air quality (incl. ozone) is measured at two plots and meteorology at one by the Norwegian Institute for Air Research (NILU).

We have participated in and contributed to several co-operative studies under ICP Forests (Seed-C, PROFILE, “Study on soil solution trends”). Time series (1991–2013) with vegetation data from two Norwegian ICP IM sites (Birkenes and Kårvatn) were uploaded to the ICP IM database at the Finnish Environment Institute. We also reported soil solution and throughfall data to the ICP IM. Time series with ozone data from two plots have been delivered from NILU to the PROFILE database.

Major results/highlights

2016 was the fourth year in Norway with the new sampling design for Level I with annually one fifth of the NFI plots monitored and five year revision intervals on the plots, following the rotation of the NFI. From 2013 on we have carried out crown condition assessments only for *Picea abies* and *Pinus sylvestris*, while damage assessments are carried out for all tree species present on the NFI plots. This new design produces good estimates of average national crown condition; however, estimates of regional crown condition are probably less accurate. In 2016, the mean defoliation for *Picea abies* was 14.6%, and 13.5% for *Pinus sylvestris*. 2016 was a year with a slight decrease in defoliation for both spruce and pine after an increase in 2015.

Of all the coniferous trees, 50.1% were rated not defoliated in 2016, which is an increase of 5%-points compared to the year before. 47.7% of the *Pinus sylvestris* trees were rated as not defoliated which is an increase of 5.3%-points. 52.2% of all Norway spruce trees were not defoliated, an increase of 4.8%-points compared to the year before.

We observed 6.1% discoloured trees for *Picea abies*, a decrease of 0.9%-points compared to the year before, and 3.3% for *Pinus sylvestris*, an increase of 0.5%-points.

In general, the observed crown condition values result from interactions between climate, pests, pathogens and general stress. According to the Norwegian Meteorological Institute the first half of the summer (June and July) of 2016 was about 1° C warmer than normal (compared to the standard reference period 1961–1990) on average for the country. August was in line with the reference period, while September was considerably warmer with 3.6° C higher than normal. This temperature increase was most pronounced in the mountains in southern Norway. Precipitation was in accordance with the reference period in June, while July and August had about 20% more rain than normal, and September 15% less. In sum, the precipitation was 115% of the reference period for the three most important months (June to August) for the drought sensitive Norway spruce, and this was important since the temperature was 1° C higher than normal in the same period. The last part of the summer is normally not so crucial for growth and mortality for conifers in Norway. There are of course large climatic variations between regions in Norway, ranging from latitudes of 58 to 71°N.

National publications/reports published with regard to ICP Forests data and/or plots

Timmermann V, Aamlid D, Økland B, Venn K (2016) Tretti år med skogovervåking. [Thirty years of forest monitoring.] In: Sundheim L, editor. Plantehelse er viktig for bioøkonomien. Plantehelseforskningen i Norge 125 år. [Plant health is important for the bioeconomy. Plant health research in Norway 125 years.] NIBIO Book 2(4):37-43. ISBN 978-82-17-01656-4.

Timmermann V. Andreassen K, Clarke N, Flø D, Nordbakken J-D, Røsberg I, Solheim H, Wollebæk G, Økland B, Aas W (2016) Skogens helsetilstand i Norge. Resultater fra skogskadeovervåkingen i 2015. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2015.] NIBIO Report Vol. 2/95: 68 pp. ISBN 978-82-17-01682-3.

Outlook

We are planning to install a new Level II site in south-eastern Norway during 2017/18.

An ICOS C-flux tower will be installed at one of our Level II sites (Hurdal), where also NILU has one of their EMEP sites, opening up for a broad collaboration between ICOS, EMEP and ICP Forests.

Poland

National Focal Centre

Jerzy Wawrzoniak and Pawel Lech, Forest Research Institute

Report on 2016 national crown condition survey

In 2016 the forest condition survey was carried out on 2001 plots (grid 8 km x 8 km).

Forest condition deteriorated compared to the previous year. 8.3% of all sample trees were without any symptoms of defoliation, indicating a decrease by 3.6 percent points. The proportion of defoliated trees (classes 2-4) increased by 2.8 percent points to an actual level 19.5% of all trees. Mean defoliation increased by 1.2 percent points to an actual level of 22.7%. Deterioration was observed for all tree species, less for conifers and higher for broadleaved. The share of trees without any symptoms of defoliation decreased by 2.9 percent points for conifers and by 5.0 percent points for broadleaves. The share of trees defoliated by more than 25% increased by 1.3 percent points for conifers and by 5.6 percent points for broadleaves. The most deterioration was observed for *Fagus sylvatica* and *Betula* spp.

In 2016 like in the previous years the condition of coniferous was better than of broadleaved species. Broadleaves were characterized by a higher proportion of healthy trees (11.2%) (by 4.5 percent points) and a significantly higher proportion of damaged trees (24.0%) (by 6.9 percent points) than coniferous (6.7% and 17.1% respectively). Mean defoliation for all species amounted to 22.7% in total, with 22.4% for conifers and 23.2% for broadleaved trees.

With regard to the three main coniferous species *Abies alba* remained the species with the lowest defoliation (16.3% trees in class 0, 17.5% trees in classes 2-4, mean defoliation amounts to 21.1%). *Pinus sylvestris* was characterized by a lower share of trees in class 0 (6.0%), also a lower share of trees in classes 2-4 (16.4%) and a little higher mean defoliation (22.3%) than *Abies alba*. Otherwise *Picea abies* was characterized by a middle share of trees in class 0 (9.2%), but higher share of trees in classes 2-4 (25.7%) and higher mean defoliation (24.2%) compared to *Pinus sylvestris* and *Abies alba*.

11.2% of assessed broadleaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2-4) amounted to 24.0%. As in the previous survey the highest defoliation amongst broadleaves was observed in *Quercus* spp. In 2016 a share of 3.4% of oak trees was without any symptoms of defoliation and 33.2% was in defoliation classes 2-4, mean defoliation amounted to 25.7%. A little better condition was observed for *Betula* spp. (6.3% trees without defoliation, 30.7% damage trees (classes 2-4) and mean defoliation amounted to 25.3%). *Fagus sylvatica* remained the broadleaves species with the lowest defoliation. In 2016 a share of 24.3% of beech trees was without any symptoms of defoliation, only 8.8% was in defoliation classes 2-4, mean defoliation amounted to 17.8%. *Alnus* spp. was more defoliated (13.0% trees without defoliation, 13.6% trees in classes 2-4, mean defoliation amount to 20.9%) than *Fagus sylvatica* and less than *Betula* spp. and *Quercus* spp.

In 2016, discolouration (classes 1-4) was observed on 0.8% of the conifers and on 1.2% of the broadleaves.

Romania

National Focal Centre

Ovidiu Badea, Romică Tomescu
National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea”

Main activities/developments

Forest Monitoring activity in Romania development during June 2016–May 2017 was based on:

- Forest monitoring activities on Level II plots as follows: crown condition assessments (12 plots); continuous and permanent measurements of tree stem variation (4 plots); collecting foliar samples for broadleaves and conifers (12 plots); phenological observations (4 plots); collecting of leaves and LAI measurements (4 plots); ground vegetation assessments (12 plots); collecting of atmospheric deposition (4 plots); air quality measurements (4 plots); meteorological measurements (4 plots)
- Intercalibration course for annual crown condition assessment
- Annual crown condition assessment at Level I plots (242 permanent plots)

- Chemical analysis for deposition samples, air pollutants passive samples (O3, NO2, NH3) and foliar nutrients
- Elaborating of the annual national reports: The Annual Report of the Romanian Environment Status in 2015, The Annual Report of the Romanian Forest Status in 2015, ICP-Forests Technical Report – 2016
- Validating and submitting of database for all monitoring activities (Level I and Level II)

Major results/highlights

Defoliation as an important proxy of forest health in the Carpathian region has shown a significant improvement of Romanian forest health status in the last decade. This can be linked with the increase of precipitation combined with relatively low increase of temperatures, and low air pollution levels.

For all species, groups of species (broadleaves and conifers) and individually, defoliation expressed by both indicators (fDEF and DEF) are slightly positively correlated with temperature and negatively correlated with precipitation, except for Norway spruce and European beech. Outside of their natural areas for spruce and other conifers, where precipitation has a slightly positive influence, temperature has a negative effect on defoliation. The temporal influence of temperature on defoliation is much lower than that of precipitation. In dry regions (south and southeast of Romania), where the most *Quercus* sp. except sessile oak are located*,* the greatest influence of precipitation that accumulated during the previous and current growing seasons was noticed. Also, in these regions (continental extreme/steppe), a slightly positive influence of temperature recorded in the previous growing season mainly occurred. In moderate climate regions (continental and sub-mountain), a greater influence of precipitation on the health status of Norway spruce and of other conifers located outside their natural areas (i.e. other than in wet climate regions) was observed. Also, in these moderate climate regions, temperature has a lower influence on defoliation than in wet climate regions, where a prolonging of the growing season contributes to an improvement in health status for beech, spruce and other conifers situated at the upper altitudinal limit of these species. Both precipitation and temperature have a small influence on beech located in the optimum area (i.e. high hills and sub-mountain regions).

Comparing with recent information focused on defoliation of the most common tree species in Europe (ICP Forests 2015) which showed an increase of this parameter in Romania, the decreasing of defoliation highlighted the importance of local environmental conditions in affecting the tree crown foliage (De Marco et al. 2014). Significant improvement of the forest health status in Romania observed in the last decade can be linked with the increase of precipitation combined with relatively low increase of temperatures, and low air pollution level (Badea et al. 2013). Despite constantly decreasing trends of averaged values of ozone (O_3), POD0 values showed increasing trends, even if not significant, highlighting a direct involvement of O_3 concentration in the defoliation trend.

The high importance of O_3 concentration in determining defoliation values for *Picea abies*, *Fagus sylvatica* and *Quercus* sp*.* in Romania is associated with a low importance of O_3 uptake.

Indeed crown condition is a specific symptom and is better related to O_3 concentration and AOT40 that are dependent on other environmental parameters, such as temperature and solar radiation. These results are in agreement with Sicard et al. (2016), where Mediterranean forests showed a closer relationship between AOT40 and specific crown damage, respect to O_3-induced visible injuries, which were more linked to the O_3 stomatal uptake.

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De Marco A, Proietti C, Cionni I, Fischer R, Screpanti A, Vitale M (2014) Future impacts of nitrogen deposition and climate change scenarios on forest crown defoliation. Environmental Pollution 194:171-180

Sicard P, De Marco A, Dalstein-Richier L, Tagliaferro F, Paoletti E (2016) An epidemiological assessment of stomatal ozone flux-based critical levels for visible ozone injury in Southern European forests. Science of the Total Environment 541:729-741

National publications/reports published with regard to ICP Forests data and/or plots

The Annual Report of the Romanian Environment Status in 2015
http://www.anpm.ro/documents/12220/2209838/RSM_2015%27.pdf/924aa8b6-429c-46f6-ac75 45f2fdd03e41 , pg 244-245.

The Annual Report of the Romanian Forest Status in 2015
http://www.mmediu.ro/app/webroot/uploads/files/2016-12-16_Raport Starea padurilor 2015. pdf

ICP-Forests Technical Report – 2016

Relevant publications

Vanguelova E I, Bonifacio E, De Vos B, Hoosbeek M R, Berger TW, Vesterdal L , Armolaitis K, Celi L, Dinca L et al. (2016) Sources of errors and uncertainties in the assessment of forest soil carbon stocks at different scales—review and recommendations. Environmental monitoring and assessment 188.11:630.

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Popa I, Badea O, Silaghi D (2016) Influence of climate on tree health evaluated by defoliation in Level I network (Romania), I-Forests.

In review

Enescu RE, Ciuvăț A, Dincă L, Iacoban C, Spârchez Gh, Deleanu E. 2017. Evolution of nutrition cycles in sessile oak (*Quercus petraea* (Liebl.)), Norway spruce (*Picea abies* L. Karst) and European beech (*Fagus sylvatica* L.) forests, Annals of Forest Research.

De Marco A, Vitale M, Popa I, Anav A, Badea O, Silaghi D, Leca S, Screpanti A, Paoletti E. 2016. Ozone exposure affects tree defoliation in a continental climate, STOTEN

Nussbaumer A, Eichhorn J, Eickenscheidt N, Fabianek P, Falkenried L, Lazdiņš A, Leca S, et al. 2017. Weather cues for mast fruiting in common beech, sessile and common oak, Norway spruce and Scots pine in Europe, Forest Ecology and Management.

Projects

- *Monitoring ozone injury for setting new critical levels* – LIFE MOTTLES, financed by European Commission – Environment Life Programme
- *Tropospheric ozone effects on forest growth and diversity* –TROZGRODIV, financed by Romanian Academy & CNR - Italy
- *Romanian forest ecosystem status - assessment and analysing in Level I and Level II monitoring networks* PN16330101, financed by Romanian Government.

Outlook

The forest monitoring activity in Romania will continue for both levels (Level I and Level II) and the infrastructure (field equipment and laboratory instruments) will be permanently actualized and modernized in order to obtain comparable results and information at European Level.

Dr. Ovidiu Badea, Dr. Stefan Leca

Serbia

National Focal Centre

Radovan Nevenic, Insitute of Forestry

Report on 2016 national crown condition survey

In the region of the Republic of Serbia, the ICP Forests 16 x 16 km grid consists of 101 sampling plots and an added 4 x 4 grid, new 29 plots, all together the number of plots is 130 (not including in assessment AP Kosovo and Metohija). Observations at Level I were performed according to the ICP Forests Manual of Methods.

During 2016, the researchers of the NFC Serbia - Institute of Forestry with collaborators from other institutions in Serbia, have worked on all sampling points and made visual assessment of the crown condition and collected the other necessary field data.

The total number of trees assessed on all sampling points was 2,973 trees, of which 332 were conifer trees and a considerably higher number i.e. 2,641 were broadleaf trees. The conifer tree species are: *Abies alba,* number of trees and percentage of individual tree species 68 (20.5%), *Picea abies* 145 (43.7%), *Pinus nigra* 67 (20.2%)*, Pinus sylvestris* 52 (15.6%). The most represented broadleaf tree species are: *Carpinus betulus,* number of trees and percentage of individual tree species 112 (4.2%) *, Fagus moesiaca* 850 (32.2%), *Quercus cerris* 535 (20.3%)*, Quercus frainetto* 394 (14.9%), *Quercus petraea* 197 (7.5 %) and other species 553 (20.9%).

The results of the available data processing and the assessment of the degree of defoliation of individual conifer and broadleaf species in percent are: *Abies alba* (None 79.4, Slight 7.4, Moderate 2.9, Severe 2.9 and Dead 7.4); *Picea abies* (None 85.5, Slight 11.0, Moderate 3.5, Severe 0.0 and Dead 0.0); *Pinus nigra* (None 35.8, Slight 23.9, Moderate 29.8, Severe 9.0 and Dead 1.5); *Pinus sylvestris* (None 84.6, Slight 7.7, Moderate 0.0, Severe 7.7 and Dead 0.0).

The degree of defoliation calculated for all conifer trees is as follows: no defoliation on 74.1% of the trees, slight defoliation on 12.4%, moderate on 8.1 %, severe defoliation on 3.6 % of the trees and 1.8% of the trees were dead.

Individual tree species defoliation (%) is: *Carpinus betulus* (None 85.7, Slight 10.7, Moderate 2.7, Severe 0.9, Dead 0.0); *Fagus moesiaca* (None 74.0, Slight 14.9, Moderate 8.2, Severe 2.4, Dead 0.5); *Quercus cerris* (None 69.7, Slight 21.9, Moderate 7.3, Severe 1.1, Dead 0.0); *Quercus frainetto* (None 85.5, Slight 9.9, Moderate 3.8, Severe 0.8, Dead 0.0); *Quercus petraea* (None 56.4, Slight 34.0, Moderate 7.1, Severe 1.5, Dead 1.0) and the rest (None 57.3, Slight 22.8, Moderate 12.1, Severe 5.1, Dead 2.7).

The degree of defoliation calculated for all broadleaf species is as follows: no defoliation 70.5% of the trees, slight defoliation 18.5% trees, moderate 7.9%, severe defoliation 2.3 % trees and dead 0.8% trees.

The data above show the presence of sample trees with moderate and severe degrees of defoliation, but this does not always signify the reduction of vitality caused by the effect of adverse agents (climate stress, insect pests, pathogenic fungi). This can only be a temporary phase of natural variability of crown density.

Slovakia

National Focal Centre

Pavel Pavlenda, National Forest Centre

Main activities/developments

Forest monitoring activities continue in the Slovak Republic at Level I and Level II to contribute to both major aims of ICP Forests. The crown condition assessment is still annually carried out in the 16x16 km grid of monitoring plots. However, the intensive monitoring activities continue only on a reduced number of Level II plots and with limited extent of surveys.

Several complementary research projects have been proposed at national level to solve specific aspects of forest ecology and forest monitoring (carbon balance, ozone injury, drought effect on forests, forest soils etc.).

Though National Forest Inventory and ICP Forests monitoring are still two independent systems, good cooperation is established between responsible teams with prospects of common outcomes for forestry.

Major results/highlights

The 2016 national crown condition survey was carried out on 103 Level I plots on the 16x16 km grid net. The assessments covered 4,244 trees, 3,547 of which were being assessed as dominant or co-dominant trees (according to Kraft crown classification). Of the 3,547 assessed trees, 40.3% were damaged (defoliation classes 2-4). The respective figures were 45.5% for conifers and 36.5% for broadleaves trees. Compared to 2015, the share of trees defoliated more than 25% increased by 5.8 percent points. Mean defoliation for all tree species together was 26.4%, with 28.0% for conifers and 25.3% for broadleaves trees. Results show that crown condition in the Slovak Republic is worse than the European average. After a clear trend of defoliation decrease in 1987–2005, the defoliation has been increasing since 2006, especially defoliation of the main broadleaved tree species (European beech, hornbeam, oaks). In 2013 the mean defoliation of broadleaves was for the first time as high as the mean defoliation of conifers.

As a part of the crown condition survey, damage types were assessed. In 2016, 28.5% of all sampling trees had some kind of damage symptoms. The most frequent damage was caused by fungi (13.1% of trees), insects (7.9%) and mechanical damage caused by harvesting (7.1%). Epiphytes had the most important influence on defoliation. Nearly 68% of trees damaged by epiphytes had defoliation above 25%.

The annual atmospheric deposition of sulphur and nitrogen are relatively stable in the last years. Sulphur deposition in throughfall varies about 5 kg ha^{-1} year^{-1} at all intensive monitoring plots (comparing with 7–20 kg ha^{-1} year^{-1} in the 90s). The total nitrogen deposition in througfall (N-NO_3 + N-NH_4) is still between 5 and 10 kg ha^{-1} year^{-1}. For most plots the deposition of N-NH_4 is higher than the deposition of N-NO_3.

The tropospheric ozone concentrations in the Carpathian Mts. are rather high, so detailed research of ozone uptake and real ozone injury is needed.

From the climatic point of view we observe a long-term and significant increase in mean annual air temperature in Slovakia. The results of biometeorological monitoring confirmed that 2016 was very warm to extremely warm and very rich in atmospheric precipitation. At a number of research plots we observed the events with very high daily precipitation or several consecutive days with rainfall. As a result, the significant periods of soil drought showed only locally and at low altitudes.

National publications/reports published with regard to ICP Forests data and/or plots

Pavlenda P, Pajtík J, Priwitzer T et al *(*2014) Monitoring of forests in Slovakia. Partial Monitoring System Forests Report. Zvolen, NLC-LVÚ Zvolen, 143 pp. ISBN 978-80-8093-195-7 (in Slovak) http://www.nlcsk.sk/nlc_sk/ustavy/lvu/vyskum/oeble/spravy_za_cms_lesy.aspx

Outlook

Monitoring of forests is a part of the Environmental Monitoring System of the Slovak Republic (one of ten partial monitoring systems such as air quality monitoring, meteorological monitoring, radioactivity monitoring, food quality monitoring) based on the decision of the Government. So the routine data collection is supported by this legislation.

Substantial additional projects and sources are needed for further development of the infrastructure and improvement of data evaluation. Current research activities focus on nutrient pools and nutrient balance in forest ecosystems as supporting basis for elaboration of Forest Bioenergy Guidelines (soil sustainability aspects). Several national projects have been proposed and submitted in national calls to solve specific items of forest ecology linked with ICP Forests monitoring aims (project for complex evaluation of atmospheric deposition in forests, project for assessment of meteorological extremes impact on growth and production of forest stands, project for integrated forest soil assessment).

Another way of cooperation with potential development of intensive forest monitoring is a better involvement of selected monitoring plots in LTER initiatives.

National data from ICP Forests are used e.g. for the improvement of National Inventory Reports of GHG balance in LULUCF sector.

Slovenia

National Focal Centre

dr. Primož Simončič, prof. dr. Tom Levanič, Daniel Žlindra, dr. Mitja Skudnik
Slovenian Forestry Institute (SFI)

Main activities/developments

Similar as in previous years, also in 2016 the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 x 16 km) (Level I). The assessment encompassed 1,056 trees, 387 coniferous and 669 broadleaved trees. The sampling scheme and the assessment method was the same as in the previous years (at each location four M6 (six-tree) plots).

In 2016 foliar assessments were carried out on all Slovenian Level II plots. Deposition and soil solution monitoring was performed on four Level II core plots and on five additional plots the ambient air quality monitoring (ozone) was done.

Major results/highlights

Crown Condition

- The mean defoliation of all tree species was estimated at 26.7%. Compared to last year the situation improved by 1.4%.
- Mean defoliation in 2016 for coniferous trees was 27.8%. In 2015 it was 29.4%.

- Mean defoliation in 2016 for broadleaved trees was 26.1%. In 2015 it was 27.3%.
- The share of trees with more than 25% defoliation (damaged trees) in 2016 decreased compared to 2015 from 37.8% to 33.8%.
- Percentage of damaged broadleaved trees decreased from 38.4% in 2014 to 31.1% in 2016.
- Especially significant is the change in the share of damaged conifer trees which increased from 38.8% in 2014 to 41.0% in 2015 but then decreased again by 2.5% in 2016 reaching the value of 38.5%.
- In 2015 and 2016 the share of damaged conifers is significantly higher than the share of damaged broadleaves.
- In 2015 and 2016 the defoliation of broadleaves decreased, but the defoliation of conifers is remaining on a very high level. The main reason is the bark beetle outbreak in the summer of 2015. In 2016 the coniferous forests were still strongly damaged from insects.

Ozone

- Average values for ozone in 2016 were 3 ppb lower than in 2015. On 4 out of 9 plots the average 14-days ozone concentration did not ascend over 40 ppb.
- The highest average 14-days ozone concentration was 50 ppb.

Deposition

- On all four Level II core plots N (nitrate, ammonium) and S (sulphate) pollutants in bulk and throughfall deposition decreased in 2015 according to previous years.

National publications/reports published with regard to ICP Forests data and/or plots

Vilhar U, Skudnik M, Ferlan M, Simončič P (2015) Tree phenology in relation to meteorological conditions and crown defoliation on intensive forest monitoring plots in Slovenia. In: Seidling W, editor. Long-term trends and effects of air pollution on forest ecosystems, their services, and sustainability: book of abstracts. Ljubljana: Slovenian Forestry Institute, The Silva Slovenica Publishing Centre, str. 47. ISBN 978-961-6425-87-2

Žlindra D, Levanič T, Rupel M, Skudnik M (2015) Degradation of Fagus sylvatica on Trnovo plateau in southwest Slovenia. In: Seidling W, editor. Long-term trends and effects of air pollution on forest ecosystems, their services, and sustainability: book of abstracts. Ljubljana: Slovenian Forestry Institute, The Silva Slovenica Publishing Centre, 2015, p. 49. ISBN 978-961-6425-87-2

Božič G, Čater M, Ferlan M et al. (2015) 30 years of forest monitoring in Slovenia, (Studia forestalia Slovenica, 145). Ljubljana: Slovenian Forestry Institute, The Silva Slovenica Publishing Centre. 59 p., ilustr. http://eprints.gozdis.si/1258/ ISBN 978-961-6425-92-6

Simončič P, Ferlan M, Kovač M et al. (2009) Monitoring report on the state of forests in y. 2015: in accordance with the Rules on forest protection (2009). Ljubljana: Gozdarski inštitut Slovenije, 2016. http://eprints.gozdis.si/id/eprint/2044.

Outlook

Current financing allows maintenance of existing infrastructure and meeting the basic requirements of the ICP Forests reporting.

Spain

National Focal Centre

Ana Isabel González, Belén Torres, Roberto Vallejo
Ministry of Agriculture and Fishing, Food and Environment, Forest Inventory and Statistics Department

Main activities/developments

Spanish forest damage monitoring comprises:

- European Large-scale forest condition monitoring (Level I): 14.880 trees on 620 plots
- European intensive and continuous monitoring of forest ecosystems (Level II): 14 plots

Level I and Level II surveys were been carried out successfully in 2016

Main activities were:

- May 2016: National Intercalibration Course
- November 2016: National Experts Meeting
- March 2017: Attendance at ICP Forests Combined Expert Panel Meeting (May 2017: Attendance at Task Force Meeting of ICP Forests and 6th ICP Forests Scientific Conference
- Others:
  - Continuous updating the website (http://www.mapama.gob.es/es/desarrollorural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimientobosques/default.aspx)
  - Participation in 19th Needle/Leaf Interlaboratory Comparison Test 2016/2017
  - Participation in 8th Deposition and Soil Solution Working Ring Test 2016/2017

Major results/highlights

Level I

There were no Level I surveys in Spain in 2015, therefore the comparison will be made with the data of the last available year (2014). This might be taken into account when interpreting results, especially in the case of the analysis of dead trees, in fact dead trees listed in 2016 correspond to two years (addition 2015 and 2016).

The Spanish forest damage monitoring comprised 14,880 trees on 620 plots in 2016. Results obtained show a general deterioration in the health condition of trees, comparing to 2014. The number of healthy trees decreased (78.2% compared to 85.1% in 2014) and trees damaged increased (18% of the trees with defoliation higher than 25%, while in 2014 this percentage was 13.2%).

The number of dead or missing trees has increased as well, 3.8% in 2016 versus 1.6% in 2014. However, it should not be forgotten that the data corresponds to a two year period. The mortality of trees is mainly due to felling operations, like sanitary cuts and forest harvesting processes, as well as to decline processes related to isolated water shortages.

General deterioration observed is more evident for species of conifers, in which group the percentage of healthy trees has decreased (79.2% compared to 88.6% in 2014), also increasing considerably was the percentage of damaged trees. Meanwhile, in the case of broadleaves, the percentage of healthy trees also decreased, although in smaller proportion (77.2% compared to 81.6% in 2014); and the percentage of damaged trees increased, although slightly. The proportion of dead or missing trees has increased in a similar way for conifers and broadleaves.

Level II

Results of Level II are complex and diverse. A summary can be obtained by consulting the publications mentioned in the next chapter.

National publications/reports published with regard to ICP Forests data and/or plots

Level I

- Forest Damage Inventory 2016 (Inventario de Daños Forestales 2016)
- Maintenance and Data Collection. European large-scale forest condition monitoring (Level I) in Spain: 2016 results. (Mantenimiento y toma de datos de la Red Europea de seguimiento a gran escala de los Bosques en España (Red de Nivel I): Resultados 2016).
  http://www.mapama.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimientobosques/ red_nivel_l_resultados.aspx

Level II

- European intensive and continuous monitoring of forest ecosystems, Level II. 2015 Report. (Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II).
  http://www.mapama.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimientobosques/ red_nivel_ll_resultados.aspx

Spanish versions are available for download.

Outlook

Nowadays, data from ICP Forests monitoring are providing very useful information to fulfil the international requirements of climate change information. Litter, deadwood and soil surveys are (and are going to be in the near future), the main source of data to assess the variation of carbon in these forestry pools.

Moreover, regional surveys are being carried out by different autonomous communities in Spain. The challenge is to assess whether they fulfill de ICP Forests Manuals or not, and if so, to evaluate the possibility of integrating the data sets into the national databases. The result would be a considerable increase of the Spanish sample.

Sweden

National Focal Centre

Sture Wijk, Swedish Forest Agency

Report on 2016 national crown condition survey

An annual monitoring of the most important sources of forest damage is carried out by the Swedish National Forest Inventory (NFI). Although the Swedish NFI is an objective and uniform inventory including data about forest damage in Swedish forests at national and regional scales, less common or less widespread occurrences of forests pests and pathogens are difficult to survey solely through large-scale monitoring programmes. Complementary target tailored forest damage inventories (TFDI) have therefor been introduced. TDFIs are developed to give a rapid response to requested information on specific damage outbreaks. The TDFIs are carried out in limited and concentrated samples, with flexible but robust methods and design.

The national results are based on the assessment of the main tree species Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) in the National Forest Inventory (NFI), and concern, as previously, only forest of thinning age or older. In total, 8,032 trees on 4,097 sample plots were assessed. The Swedish NFI is carried out on permanent as well as on temporary sample plots. The permanent sample plots, which represent about 60 percent of the total sample, are remeasured every 5th year.

The proportion of trees with more than 25 % defoliation is for Norway spruce 22.8% and for Scots pine 11.5%. An improvement is seen for Norway spruce in southern Sweden in 2016 after the slight increased defoliation seen during the last ten years. A slight improvement is noticed on Norway spruce in northern Sweden during recent years. In all Sweden defoliation in Scots pine has decreased in 2016 after a period of increasing defoliation. There are some large temporal changes seen in defoliation levels at regional level however the majority of changes during recent years are minor.

A few minor storms affected Sweden in 2016. There are wind-felled trees in small groups found spread over a large area in central Sweden. In October 2016 an estimated volume of 0.3 million m^3 of wind-felled spruce trees still were available for breeding by barkbeetles. Approximately 0.2 million m^3 of spruce trees were killed by barkbeetles, mainly *Ips typographus* and *Polygraphus* sp. The barkbeetle populations has increased and it is likely that this will lead to further damage to the growing forest.

The decline in Ash (*Fraxinus excelsior*) is continuing in southern Sweden. Severe problems with Dutch elm disease (*Ophiostoma novo-ulmi*) remain. In northern Sweden problems with resin top disease (*Cronartium flaccidum*) still occur in young pine stands. In southern Sweden damage in young pine caused by Diplodia blight (*Diplodia pinea*) were found. Due to changing climate conditions there is a fear of northward expansion of this disease. Overall however the most important biotic damage problems are, as previously, due to pine weevil *(Hylobius abietis*) (in young forest plantations), browsing by ungulates - mainly elk (in young forest), and root rot caused by *Heterobasidion annosum*.

Switzerland

National Focal Centre

Peter Waldner, Marcus Schaub, Arthur Gessler
WSL, Swiss Federal Institute for Forest, Snow and Landscape Research

Main activities/developments

Besides the regular monitoring activities and data analyses on the Level I and Level II plots particular emphasis was put on the following topics:

- Analysis of masting patterns of most important tree species within Switzerland (Wohlgemuth et al. 2016) and at Europe scale (Nussbaumer et al 2016, ICP Forests Project Nr. 91 ‘Seed-C 2’) based on the Crown Condition Surveys.
- For ozone risk assessment, particular emphasis was put on parameterizing DO3SE to quantify the flux-response relationships under field conditions across Switzerland – in comparison to the EMEP and AOT40 approach.
- The analyses of the effects of climate and Impacts of site quality, air quality and climate on growth of European forest ecosystems carried out within the EU FP7 project Eclaire (c.f. ICP Forests Project

Nr. 15 'Eclaire') were finalized and a publication (Etzold et al.) will be submitted in the first half of 2017.

Major results/highlights

The Crown Condition survey on the Level I plots (16x16km grid) in 2016 revealed that the decreasing defoliation trend that was apparent in 2015 stabilised with the proportion of significantly damaged trees (trees showing unexplained defoliation subtracting the percentage of defoliation due to known causes such as insect or frost damage) between 30% and 100% (class 2-4) remaining approximately constant between 2015 (24.7%) and 2016 (25.3%). These values are close to the long-term average of the last twenty years, which is 23.3%. Late frosts in spring 2016 caused an increased defoliation of beech but only in an altitudinal band between approx. 800 and 1100 m asl.

In the Valais, a typically rather dry inner-alpine valley, intensive die-back events of Scot pines at lower altitude (including Level II plot 14) have been observed by forest services in Autumn 2016 – the hot summer 2015 and the dry second half of 2016 might be responsible for this increased mortality (Rebetez & Dobbertin 2004) and we will continue to assess causes for the strong tree mortality in this region.

The results of the ozone risk assessment demonstrate that data completeness is the most crucial factor affecting the quality of the data series. Furthermore, passive ozone samplers seem to provide reliable concentration values. However, compared to the other approaches, the approach by Ferretti *et al*. (2012) seems to overestimate AOT40. The Pod1 values from all applied approaches, except for the EMEP approach, are all in the same range. This is very reassuring, demonstrates the robustness of the DO3SE approach and increases the confidence in the data and applied parameterizations for 9 LWF plots (c.f. interactive map at at https://www.wsl.ch/apps/ozone)

National Studies

A campaign of NH_3 and NO_x measurements with passive samplers including 14 open field stations of Level II sites carried out in 2014 were used to compare inferential models and canopy budget models to estimate N deposition (Seitler et al. 2016). Tomlinson et al. (2016) sampled trees close to 6 Level II sites and found temporal correlations of stable isotopes composition of foliage and tree rings for 13C, but not for 15N. Millhaeuser et al. (2016) explained parts of the visitor frequency variation in the Swiss National Park using meteorological measurements of the Level II plot. With a soil sampling campaign at selected Level II and other sites in 2014, Van der Voort (2016) determined the 'age' of soil organic matter based on the 14C isotopic signal. They found less relations of age increase trends with depth to climatic factors than expected. Level I mortality and Level II nitrate leaching data were further used in research projects of the Swiss Program 'Forests under Climate Change' (e.g. Waldner et al. 2016).

Outlook

In 2017, the data acquisition and transmission modules of the meteorological stations at the Level II plots (pairs of stations within and outside forests) will be replaced due to changes in the cellular phone network, and will enable to run phenology cameras. Currently, precipitation measurement with weighing units is tested and a prototype for a data portal developed.

Parallel NH_3 passive sampler measurements above forest canopy and at the open field station are planned for one Level II plot (Nr. 15). An EMEP station currently located at a Level II plot (Nr. 19) will be moved away and the long-term continuous on-site NO_x and O_3 measurements will end in 2017. Regarding ozone risk assessment, new and additional 2BTech ozone monitors are needed to increase the data completeness on Level II plots that is crucial to continue the planned further analyses of dose-response relationships based on the AOT40 and POD1 values obtained from DO3SE.

The size of the subplots for the Crown Condition Assessment (CC) will be reduced to a fixed 0.25 ha area on all Level II plots and the CC assessment will be stopped on 2 to 3 plots (e.g. plot 6, 17, and 9) from 2017 onwards. Growth Assessment will be started on some plots in the coming years and no longer be carried out simultanously.

Publications regarding the National ICP Forests plot network

Waldner P, Braun S, Kurz D, Thimonier A (2016) Nutrient Fluxes in the Forest with a focus on nitrogen and basic cations (in German). In: Pluess A. R., Augustin S., Brang P. (eds.) Forests under Climate Change. Fundamentals for adaptation strategies. Swiss Federal Office for Environment BAFU, Bern; WSL, Birmensdorf. Haupt Verlag, Bern, Stuttgart, Wien, 61-73

Seitler E, Thöni L, Meier M (2016) Atmosphärische Stickstoff-Deposition in der Schweiz 2000 bis 2014. Rapperswil, FUB – Forschungsstelle für Umweltbeobachtung, 105 p. https://www.bafu.admin.ch/dam/bafu/de/dokumente/luft/externe-studien-berichte/atmosphaerische_stickstoff-depositioninderschweiz2000bis2014.pdf

van der Voort T S, Hagedorn F, McIntyre C, Zell C, Walthert L, Schleppi P, Feng X, Eglinton T I (2016) Variability in 14C contents of soil organic matter at the plot and regional scale across climatic and geologic gradients. Biogeosciences 13(11):3427-3439

Tomlinson G, Buchmann N, Siegwolf R, Weber P, Thimonier A, Graf Pannatier E, Schmitt M, Schaub M, Waldner P (2016) Can tree-ring δ15N be used as a proxy for foliar δ15N in European beech and Norway spruce?. Trees - Structure and Function 30:627–638. DOI: 10.1007/s00468-015-1305-1

Millhäusler A, Anderwald P, Haeni M, Haller R M (2016) Publicity, economics and weather – Changes in visitor numbers to a European National Park over 8 years. Journal of Outdoor Recreation and Tourism 16:50-57

Zweifel R, Haeni M, Buchmann N, Eugster W (2016) Are trees able to grow in periods of stem shrinkage?. New Phytologist 211(3):839-849

Publications regarding European Scale ICP Forests plot network

Calatayud V, Diéguez JJ, Sicard P, Schaub M, De Marco A (2016) Testing approaches for calculating stomatal ozone fluxes from passive sampler. *Science of the Total Environment* 572:56-67. DOI: 10.1016/j.scitotenv.2016.07.155

Schaub M, Haeni M, Ferretti M, Gottardini E, Calatayud V (2016) Ground level ozone and its impact on European forests. *In*: Sanders TGM, Michel AK, Ferretti M (eds.). 30 years of monitoring the effects of long-range transboundary air pollution on forests in Europe and beyond UNECE/ICP Forests, Eberswalde. Page 51-56. ISSN 1020-587X, e-ISSN 2198-6541

Gottardini E, Calatayud V, Ferretti M, Haeni M, Schaub M (2016) Spatial and temporal distribution of ozone symptoms across Europe from 2002 to 2014. *In*: A. Michel and W. Seidling (eds) Forest Condition in Europe: 2016 Technical Report of ICP Forests. Report under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). Vienna: BFW Austrian Research Centre for Forests. BFW Dokumentation 23/2016. 210 p. ISBN 978-3-902762-65-8

Nussbaumer et al (2016) Patterns of mast fruiting of common beech, sessile and common oak, Norway spruce and Scots pine in Central and Northern Europe. Forest Ecology and Management 363:237-251

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Rebetez, M.; Dobbertin, M., 2004: Climate change may already threaten Scots pine stands in the Swiss Alps. Theor. Appl. Climatol. 79:1-9

Turkey

National Focal Centre

Sıtkı Öztürk, General Directorate of Forestry

Report on 2016 national crown condition survey

Monitoring studies have been conducted on a grid of 16x16 km and crown condition of 13,547 trees in 586 Level I sample plots have been evaluated in 2016. Average needle/leaf loss ratio of all evaluated trees is 16.0%. The ratio of healthy trees (class 0-1) is 90.2% and the remaining 9.8% has a loss ratio of greater than 25 percent. Annual average needle/leaf loss increased by about 2.4% in comparison to the last year (2015).

The average defoliation ratio of broadleaved species is 16.6% percent. Common tree species with the highest defoliation ratios are *Quercus petraea* (20.8%), *Quercus pubescens* (20.7%) and *Castanea sativa* (20.3%), respectively In comparison to year 2015 a slightly improvement in these species was observed. Among the less common broadleaved species (each of which are presented by less than 20 individuals), *Fraxinus ornus, Ceratonia siliqua, Juglans regia, Ostrya carpinifolia, Pistacia lentiscus* and *Prunus avium* have 25 % or greater defoliation ratio. While 89.0% of all broadleaved trees showed no or slight defoliation (class 0-1), 11.0% of them defoliated by more than 25% (class 2-4).

The average defoliation ratio of coniferous species is 15.7%. 91.0% of all evaluated coniferous trees have needle loss of less than 25% (class 0-1), and the remaining 9.0% of them have over 25% needle loss (class 2-4). *Pinus pinaster, Pinus brutia, Abies cilicica,* Junipers (*Juniperus communis, J. excelsa, J. oxycedrus, J. foetidissima*) have the highest needle loss among common conifers with defoliation ratios between 21.8% and 15.3%. As for pine species, defoliation ratios of *P. brutia*, *P. sylvestris* and *P. nigra* are 18.1%, 14.6% and 13.0%, respectively. In addition, the greatest needle loss was observed in *P. pinaster* (21.8%), which is a less common species and represented by only 14 sample trees in this monitoring study.

Among the biotic causes of damage, *Thaumetopoea* spp., *Tomicus* spp, *Rhynchaenus fagi, Cinara cedri* and *Cryphonectria parasitica* are the most pronounced species. Number of trees affected by *Thaumetopoea* spp. is almost the same in comparison to the last year. As in previous years, mistletoe (*Viscum alba*) is also among the leading damaging agents.

United Kingdom

National Focal Centre

Suzanne Benham, Forest Research

Main activities/developments

The Level 2 plot network has been maintained during 2016. Monitoring activities continue at five sites. Sample collections for deposition, soil solution, litter fall and soils have been carried out. Monthly growth recording using permanent girth tapes continues and vegetation surveying was undertaken as part of the 3 yearly monitoring cycle. Two sites have been clear-felled this year as the crop reached maturity in line with UK standard practice. Re-sampling of the forest soils was carried out at both plots according to ICP sampling methodology prior to harvesting. During harvesting dendrochronology discs were removed from a cross sample of trees within the plot for analysis. The remaining plots which currently have no continuously monitoring activities are still available for research. In addition to the felled plots repeated soil surveying has been carried out at all remaining Level 2 plots. For the Sitka Spruce sites this is the 3rd sampling (1994, 2008, 2016), whilst for the oak and SP sites it is the second (1994, 2016). The soil carbon stock and change values and associated data generated from the ICP Forests monitoring has been used as inputs for development and testing of a new dynamic forest soil carbon model.

Greenhouse gas collars have been installed at our remaining Sitka spruce site (919, Coalburn) to establish a soil GHG emission baseline prior to the eventual harvesting of the crop. The aim is to allow us to quantifying the impact of harvesting on soil GHG emissions.

GHG monitoring using a Eddy co-variance system has continued at the Alice Holt (512) oak site since 2007. Monthly measurements of forest floor GHG fluxes (CO_2, CH_4 and N_2O) in the oak plantation, including the Level II site, over 3-5 years have been analysed (in press in Forestry) and will help to quantify the CO_2 emissions, show the very low N_2O efflux at this site, and highlight the role of mineral forest soils as a small CH_4 sink.

The quantification of deadwood biomass and carbon stocks from a subset of UK ICP Level II sites plus all UK Biosoil plots has been undertaken and a new PhD studentship will work on quantifying the release of carbon (as CO_2 and DOC) from deadwood.

Tea bags were buried in seven Level II plots plus 45 BioSoil plots as part of the European TBI initiative to allow the quantification of decomposition rates within each plot and soil type.

Major results/highlights

Triple isotopes (C, N, O) in deposition and throughfall to understand the nitrogen transformation by forest canopies. This study has led to a larger European Marie Curie funded project from 2016-2019.

National publications/reports published with regard to ICP Forests data and/or plots

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Outlook

Future development

- Funding remains under tight constraints in the UK. From the original network of 10 monitoring sites monitoring obligations under ICP Forests continue at five sites.
- Continual monitoring activities at the remaining five sites have been suspended but we continue to keep a watching brief on these sites and will carry out final crop measurement etc. at felling time. At present there are no plans to expand our monitoring activities beyond this.

Planned research projects, expected results

- Analysis of vegetation change over 25 years at Level II plots
- Nutrient accounting
  - Long term nutrient flux change over monitoring period
  - Nutrient budgets of all Level II sites
  - Nutrient translocation of masting
  - Nutrient from masting and their release to soils
  - Soil nutrient stocks at Biosoil plots

ANNEX

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