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Forest Condition in Europe
2019 Technical Report of ICP Forests

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

Alexa Michel, Anne-Katrin Prescher & Kai Schwärzel (Eds.)

LRTAP Long-range Transboundary Air Pollution

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

BFW Bundesforschungszentrum für Wald

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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. 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 at the end of this document.

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United Nations Economic Commission for Europe (UNECE)
Convention on Long-range Transboundary Air Pollution (Air Convention, formerly CLRTAP)
International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

http://icp-forests.net

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 (Air Convention or 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 2019 Technical Report presents results from 31 of the 42 countries participating in ICP Forests. Part A presents **research highlights from the January–December 2018 reporting period**, including:

- a review of 34 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure were used;
- a list of the presentations at the 7th ICP Forests Scientific Conference in Riga, 22–23 May 2018;
- a list of all 46 research projects using ICP Forests data/infrastructure and ongoing for at least one month between January and December 2018.

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

- atmospheric throughfall deposition in European forests in 2017;
- activities to improve data quality in ozone symptom assessment within the Expert Panel on Ambient Air Quality;
- tree crown condition in 2018.

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

Online supplementary material complementing Chapter 7 on tree crown condition in 2018 is available online[1].

For contact information of all authors and persons responsible in this programme, please refer to the annex at the end of this document. For more information on the ICP Forests programme, we kindly invite you to visit the ICP Forests website[2].

Following is a summary of the presented results from regular evaluations in ICP Forests (Part B).

Studying the effects of atmospheric pollution to forest ecosystems requires an evaluation of air quality and of the amount of pollutants carried to the forests by atmospheric deposition. In 2017, the chemical composition of open field bulk and below canopy throughfall deposition was measured on 278 and 297 intensive monitoring (Level II) plots, respectively, including data from 27 and 49 plots kindly provided by the Swedish Throughfall Monitoring Network (SWETHRO). **Chapter 5 focuses on atmospheric throughfall deposition of acidifying, buffering, and eutrophying compounds in 2017.**

High throughfall deposition of nitrate was mainly found in Central Europe (Germany, Switzerland, the Czech Republic, Austria and Belgium-Flanders), while for ammonium high deposition was also found in northern Italy, southwestern UK, southern Romania and western Poland. The area of high deposition is smaller for sulphate, including some plots in Hungary, Greece, the Czech Republic, Slovakia, Bulgaria, and in Belgium-Flanders near the port of Antwerp. High values in coastal areas are partially due to deposition of marine aerosol, and they are less evident after sea-salt correction.

Calcium, potassium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium throughfall deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in Eastern Europe. The correction for the marine contribution does not affect their spatial pattern. On the contrary, in the case of magnesium, the distribution of the highest values is markedly reduced by the sea salt correction.

It is important to note that the total deposition to the forest can be higher (typically for nitrate and ammonia) or lower (typically for buffering compounds) than the throughfall deposition, due to canopy exchange processes.

Data quality is a key issue in ICP Forests. It has been considered since the beginning of the ICP Forests programme, and properly addressed through the adoption of specific, dedicated activities. **Chapter 6 describes activities to improve data quality in ozone**

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

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

symptom assessment within the Expert Panel on Ambient Air Quality. It reports (i) on the intercalibration courses since 2000 up to now organized by the EP AAQ, and (ii) on the results obtained with the photo and field exercises carried out during the ICCs. In addition, the following initiatives undertaken to improve data quality for ozone visible symptom validation are also described: (iii) the online tool OSVALD (Ozone Symptom VALidation Database) and (iv) the microscopic analysis of leaves.

Providing data with a certain quality, the survey on ozone visible symptoms carried out by the EP AAQ – the largest European programme in assessing ozone levels and effects on vegetation – will permit to obtain a large-scale, long-term picture of the risk that ozone poses on European forests.

Chapter 7 on tree crown condition in 2018 presents results from the assessments carried out on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests, as well as long-term trends for the main tree species and species groups.

The transnational crown condition survey in 2018 was conducted on 110 277 trees on 5 634 plots in 27 countries. Out of those, 103 797 trees were assessed in the field for defoliation. The overall mean defoliation for all species was 22.6% in 2018, and there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2017. Broadleaved trees showed a slightly higher mean defoliation than coniferous trees (22.9% vs. 21.3%). Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (26.1% and 25.8%, respectively). Common beech had the lowest mean defoliation (20.8%) followed by Norway spruce with 21.0% deciduous (sub-) Mediterranean oaks (21.2%) and Mediterranean lowland pines (21.3%). The strongest increase in defoliation from 2017 to 2018 occurred in deciduous temperate oaks (+2.2%) while evergreen oaks had the largest decrease in defoliation (-1.8%). Overall, the differences in defoliation between 2017 and 2018 are not very large.

In 2018, damage cause assessments were carried out on 103 714 trees on 5 505 plots in 26 countries. On 47 327 trees (45.6%) at least one symptom of damage was found, and 711 trees (0.7%) were dead. On 1 221 plots no damage was found on any tree.

Insects were the predominant cause of damage and responsible for 27.3% of all recorded damage symptoms. Almost half of the symptoms caused by insects were attributed to defoliators (47.3%), the most frequent of all specified damage causes.

Abiotic agents were the second major causal agent group responsible for 16.4% of all damage symptoms. Within this agent group, more than half of the symptoms (49.7%) were attributed to drought, while snow and ice caused 9.6%, wind 8.0%, and frost 3.7% of the symptoms.

CONTENTS

ONLINE SUPPLEMENTARY MATERIAL complementing Chapter 7 on Tree Crown Condition in 2018 is available at http://icp-forests.net/page/icp-forests-technical-report

1 INTRODUCTION

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 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 groups (six ICPs, a joint Task Force with WHO, and the Joint Expert Group on Dynamic Modelling) that report to the Working Group on Effects (WGE) under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention or CLRTAP) on the effects of air pollution on a wide range of ecosystems, materials, and human health.

ICP Forests monitors forest condition at two intensity levels:

- The **Level I monitoring** is based on 5 636 observation plots (as at 2018) 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.
- The **Level II intensive monitoring** comprises 592 plots (as at 2017, Table 1-1) 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[1] ensures a standard approach for data collection in forest monitoring among the 42 participating countries.

With climatic changes and their effects on forest ecosystems in Europe and beyond having become more and more evident over the recent years, forest monitoring has proven to be as relevant as ever. The yearly published ICP Forests Technical Report series summarizes the programme's annual results and has become a valuable source of information on European forest ecosystem changes over time. Important activities and developments in the last reporting period are as follows.

Programme highlights in 2018

People

- We are very sad that **Bohumír Lomský** passed away in September 2018. He had been with the programme since the mid-1990s and was in charge of the National Focal Centre of Czechia since 2001. We will remember him as an amiable person and proficient and committed scientist.
- Much to our regret **Dr Karin Hansen** left the ICP Forests, a dedicated member of the community since 1994, who particularly advanced the programme as Chair of the Expert Panel on Deposition (2010-2017) and Chair of the Scientific Committee (2017-2018). We wish her all the best in her new position with the Swedish EPA.
- **Dr Walter Seidling** retired from his position as PCC Head in October 2018. We are very grateful for Walter's efforts and dedication for the last six years.

Data Unit

- 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:
  - an open data dataset describing the plots and data availability (decision of the Task Force in 2018)
  - concept for a new ICP Forests website including a new mapping application
  - general revision of the data model (database structure) to harmonize data series over time.

Reporting

- The new **ICP Forests Brief**[2] series aims to provide clear and concise information on the ICP Forests monitoring programme and its latest scientific findings. These short updates were developed to primarily address policymakers and the interested public and offer them scientific knowledge for an informed debate on key forest-related environmental topics.

Meetings

- The **7th ICP Forests Scientific Conference** *European forestst in a changing environment: Air pollution, climate change and forest management* was hosted by the Ministry of Agriculture of the Republic of Latvia and the Latvian State Forest Research Institute (SILAVA) in Riga, 21–23 May 2018, with 84 participants from 26 countries.

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

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

The directly following **34th ICP Forests Task Force Meeting** was attended by 55 participants from 27 countries.

- The **Expert Panels on Biodiversity and Ground Vegetation; Forest Growth; Meteorology, Phenology and Leaf Area Index; and on Ambient Air Quality** met in Zvolen, Slovakia, 1–5 October 2018 to discuss the current status and future developments of the programme in the different surveys.

- The **14th ICP Forests Intercalibration Course on ozone symptom assessment** was held in Poreč, Croatia, on 10–13 September 2018 and attended by 22 participants from 13 countries.

- The ICP Forests 9th Soil, 9th Deposition/Soil Solution, and 21st Needle/Leaf Interlaboratory Comparisons 2018/19 started.

- The **6th Saltsjöbaden workshop on Clean Air for a Sustainable Future – Goals and Challenges** directed at policy makers, scientists and stakeholders active in supporting air pollution awareness and control on an international scale was held in Gothenburg, Sweden, 19–21 March 2018.

This 2019 Technical Report of ICP Forests, its online supplement, and other information on the programme can be downloaded from the ICP Forests website[1]. Please send your comments and suggestions to pcc-icpforests@thuenen.de; we highly appreciate your feedback.

Participants at the 7th Scientific Conference and/or 34th Task Force Meeting of ICP Forests in Riga, 21–25 May 2018, representing 27 countries

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

Table 1-1: Overview of the number of Level II plots used in different surveys by the participating countries in 2017 as submitted to the ICP Forests database by 7 May 2019.

	Air quality	Crown condition	Deposition	Foliage	Ground vegetation	Ground vegetation biomass	Growth and yield	Leaf area index	Litterfall	Meteorology	Ozone	Phenology	Soil solution
Austria			15	15					6	6			
Belgium	5	8	9		11			5				5	9
Bulgaria	4	4	4		4				3	4	2	1	3
Croatia	2	7	4	7			6		4	2	2	4	
Cyprus	1	4	2							2			2
Czechia		16	7	6			7		7	11		6	7
Denmark		4	4	4	4	4	3		4	4		3	4
Estonia		6	6	6					1	1			5
Finland			11	10			5			12		2	12
France		94	25	93			8		12	13		84	14
Germany	44	80	82	63	45	16	28	30	66	76	17	49	73
Greece		4	3	4					4	4	4	2	
Hungary			10					7		8			
Italy		30	8										6
Latvia	1	2	3	3					3				3
Lithuania	3	9	3	9					3	1	9	3	3
Norway		3	3	3									3
Poland	12	138	12	12									12
Romania	4	12	5	4	12		4	3	3	4		3	5
Serbia		5	5		5		1		5	5	5	5	3
Slovakia	2	8	7							6			4
Slovenia	9	10	4	10									4
Spain	14	14	14	14			14	14	14	14	14	14	5
Switzerland	7	18	14							18	9		9
Turkey		52											
UK			5	4			3		4	5			5
Total	**108**	**528**	**265**	**267**	**81**	**20**	**79**	**59**	**139**	**196**	**62**	**181**	**191**

Part A

ICP FORESTS-RELATED RESEARCH HIGHLIGHTS

2 OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY – DECEMBER 2018)

Between January and December 2018, 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 overview includes all 34 English online and in print publications from 2018 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[1]. For a list of all 34 ICP Forests-related publications, please refer to the end of this chapter.

This is a compilation made by the PCC summarizing the publications by primarily verbally citing and slightly editing the information given in the publications' abstracts. For better reading, however, citations are not given in quotation marks.

Atmospheric deposition

Although explaining the large-scale diversity of soil organisms that drive biogeochemical processes and their responses to environmental change is critical, identifying consistent drivers of belowground diversity and abundance for some soil organisms at large spatial scales remains problematic. Van der Linde et al. (2018) investigated ectomycorrhizal fungi across European forests at a spatial scale and resolution to explore key biotic and abiotic predictors of ectomycorrhizal diversity and to identify dominant responses and thresholds for change across complex environmental gradients. They showed the effect of 38 host, environment, climate and geographical variables on ectomycorrhizal diversity, and define thresholds of community change for key variables. The authors quantified host specificity and reveal plasticity in functional traits involved in soil foraging across gradients. They conclude that environmental factors like the nitrogen input and host factors explain most of the variation in ectomycorrhizal diversity, that the nitrogen deposition thresholds used need adjustment, and that the importance of belowground specificity and plasticity has previously been underappreciated.

Krupová et al. (2018) assessed the spatial and temporal variation of atmospheric open field (bulk) deposition of sulphur, ammonium and nitrate nitrogen on 14 permanent ICP Forests Level II monitoring plots in Czechia and Slovakia for the years 2000–2016. Sulphur deposition showed the most significant change with a strong decrease on Slovak plots and a slightly milder decrease on Czech plots. Regarding NO_3^- deposition, they found small spatial and temporal differences with statistically more significant decreases in Slovakia than in Czechia. The smallest changes were in annual depositions of NH_4^+, although the deposition was statistically significant in Slovakia but dropped only slightly over most of the territory in Czechia during the evaluated period. In both countries, sulphur and nitrogen depositions persistently rank among the highest in Europe.

Vuorenmaa et al. (2018) evaluated long-term trends (1990–2015) for bulk deposition, throughfall and runoff water chemistry and fluxes, and climatic variables in 25 forested catchments in Europe belonging to the ICP Integrated Monitoring, of which some also function as ICP Forests sites and belong to the LTER-Europe and international LTER networks for long-term ecosystem research. They found that concentrations and fluxes of non-marine sulphate (SO_4^{2-}) in runoff have substantially decreased at 90% and 60% of the investigated sites, respectively. Bulk deposition of inorganic nitrogen decreased significantly at 60–80% (concentrations) and 40–60% (fluxes) of the sites, respectively. Yet, climatic variables and deposition explained the variation of inorganic N concentrations in runoff at single sites poorly. Overall, their results confirm the positive effects of the emission reductions in Europe.

In Mediterranean areas, dry deposition is a major component of the total atmospheric N input to forest ecosystems. To estimate total dry deposition of inorganic nitrogen in four holm oak forests in Spain, García-Gómez et al. (2018) used an innovative approach: They combined the empirical inferential method (EIM) for surface deposition of NO_3^- and NH_4^+ with the stomatal uptake of NH_3, HNO_3 and NO_2 derived from the DO_3SE (Deposition of Ozone and Stomatal Exchange) model. They found the highest total deposition at the northern site (28.9 kg N ha^{-1} $year^{-1}$) and the lowest at the central-Spain site (9.4 kg N ha^{-1} $year^{-1}$), matching the geographical pattern previously found in model estimates. On average, the estimated dry deposition of atmospheric nitrogen was around 77% of the total nitrogen deposition, of which surface deposition of gaseous and particulate atmospheric N averaged 58% of the total deposition, and stomatal uptake of N gases averaged 19% of the total deposition. In this study, the empirical critical loads provisionally proposed for ecosystem protection were exceeded at three of the four investigated sites.

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

Nutrient cycling

Nutrient remobilization is a key process in nutrient conservation in plants and in nutrient cycling in ecosystems. Based on data from 102 Level II plots in France, Achat et al. (2018) determined the total amounts or availability of nutrients in soils, the quality of soil organic matter (C:N and C:P ratios) and K-Ca-Mg antagonisms, plant-related parameters (nutrient concentrations in foliage and leaf life span) and climate variables (e.g., precipitation and actual evapotranspiration). They established that all of these variables affected the nutrient remobilization rates in tree foliage of several major nutrients (N, P, S, K, Ca, and Mg), with soil nutrient richness and leaf life span generally being the two most important factors. The authors conclude that the availability–remobilization relationship can be generalized to contrasting pedological contexts and is applicable to all major nutrients.

Neumann et al. (2018) used litterfall observations from 320 ICP Forests plots to quantify carbon and nutrient input, to evaluate existing litterfall estimation models, and to determine the litterfall contribution to carbon and nutrient cycling in European forests. The 1604 analyzed annual litterfall observations indicated an average carbon input of 224 g C m^{-2} $year^{-1}$, representing a substantial percentage of NPP from 36% in northern Europe to 32% in central Europe. The annual turnover of carbon and nutrients in broadleaf canopies was larger than for conifers. They conclude that the evaluated models provide large-scale litterfall predictions with a bias less than 10%, however, the performance of litterfall models may be improved by including foliage biomass and proxies for forest management.

To understand the controls on the terrestrial carbon transfer to the atmosphere, the TeaComposition initiative used standardized substrates (Rooibos and Green tea) for comparison of litter mass loss at 336 sites in different ecosystems of nine biomes all across the globe, also including ICP Forests sites. The results published by Djukic et al. (2018) indicate that multiple drivers are affecting early stage litter mass loss with litter quality being dominant, while the effect of climate was only important under less favorable climatic conditions and when data were aggregated at the biome scale. No significant effect of land-use on early stage litter decomposition was found within the temperate biome, in which 74 % of the sites of this study were situated. The TeaComposition initiative will perform additional samplings after 12, 24, and 36 months to investigate long-term litter decomposition dynamics.

Ozone

Tropospheric ozone (O_3) concentrations from passive samplers have been monitored according to harmonized methodologies on ICP Forests intensive monitoring (Level II) sites since the year 2000 with the aim to (i) quantify ozone concentrations during the vegetation period (April-September), (ii) estimate the related ozone exposures of forest ecosystems, and (iii) detect temporal and spatial trends across Europe. Over the years ozone concentrations have decreased, but exposure still remains high in European forests (ICP Forests Brief No.3[1]).

The specific effect of ozone on forest trees, however, remains unclear. Ferretti et al. (2018) concluded that tropospheric ozone was not a significant factor in explaining the recent status and trends of tree health (in terms of defoliation) and productivity (in terms of basal area increment (BAI)) on 15 ICP Forests Level I and one Level II plot in alpine forests in northern Italy. Both, defoliation and BAI were rather driven by biotic/abiotic damage, nutritional status, DBH (assumed as a proxy for age), and site characteristics.

Ciriani and Dalstein (2018) also found no correlation between ozone and defoliation. They had monitored foliar ozone damages of three conifer and three broadleaf species and ozone concentration from 2013 to 2015 on a selection of 15 permanent French Level II forest plots. From the investigated conifers, Scots pine (*Pinus sylvestris*) was more affected by ozone than silver fir (*Abies alba*) and Norway spruce (Picea abies). In the broadleaves, European beech trees (*Fagus sylvatica*) were more sensitive to ozone than sessile and pedunculate oak (*Quercus petraea*, *Q. robur*). In 2015, an unusual warm year at global level, the measured ozone concentrations were also higher compared to 2013 and 2014, and leaf damage occurred at most of the studied sites, even on fir trees which are regarded as less sensitive to ozone.

A 10-year long dataset (2005–2015) of half-hourly ozone (O_3) fluxes was used to study the variability in deposition velocity (v_d) over a mixed temperate suburban forest in Belgium (Neirynck and Verstraeten 2018). It was found that the precipitation form had a marked impact on v_d and the deposition efficiency (v_d/v_{dmax}), with highest values measured when the canopy was dew-wetted or covered with snow. The analysis further evidenced that traffic volume led to increased deposition due to the presence of chemical reactions between ozone and nitric oxide above the canopy surface. Monthly average night-time/daytime v_d and v_d / v_{dmax} were positively correlated with the relative humidity at the canopy surface and negatively correlated with soil water. During the daytime, monthly v_d and v_d / v_{dmax} were additionally increased during the working-week when traffic volume was high.

So although the mechanisms of ozone impacts on the physiological processes in trees are more and more understood, the long-term effects of ozone on tree growth and forest composition and structure in European forests remain

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

controversial because of the large variability among sites, species, data sources and methodological approaches. This led Cailleret et al. (2018) to provide a comprehensive review of the empirical and modelling approaches available for ozone risk assessment. They also provide a roadmap to quantify ozone effects on forest growth, from stand to European scale, by combining ozone-controlled experiments and long-term monitoring data with physiological and forest succession process-based models.

Heavy metals

Under the Air Convention more emphasis has recently been given to the assessment of heavy metals in forest ecosystems but only few data have so far been collected across Europe. Michopoulos et al. (2018) determined the concentrations of the heavy metals arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb) as well as the isotopic 206Pb/207Pb composition in soil layers for the hydrological years 2012/13 and 2013/14 in a remote mountainous Bulgarian fir (*Abies borisii regis* M.) forest in central Greece. The concentrations of metals in the hydrological cycle (bulk deposition and throughfall) were lower than in the past in Europe, especially for Pb. Litterfall consisting of mosses, lichens, insect frass and pollen had higher concentrations of all heavy metals than needle litterfall. An evidence for the significance of dry deposition was that all metals had higher concentrations in older than in younger needles with the exception of Ni. In all compartments of the standing trees, the order of concentrations was Ni>Pb>Cr>Cd>As. The concentrations of heavy metals in the ground vegetation were low with the exception of Cd, Cr and Ni in ferns. The concentrations of heavy metals in the FH horizon and mineral soil followed the order Cr>Ni>Pb>As>Cd, whereas in the L layer Ni had the highest value.

Soil

In addition to requesting data from the ICP Forests database, the archived soil samples collected during forest monitoring can also be used by researchers for further measurements, as in the following two studies by Soucémarianadin et al. (2018a, 2018b).

Soil respiration tests and abundance of particulate organic matter (POM) are considered classical indicators of the labile soil organic carbon (SOC) pool. However, there is still no widely accepted standard method to assess SOC lability. Using a large set of samples (n = 99) of forest soils from 53 French Level II plots representing contrasting pedoclimatic conditions, including deep samples (up to 0.8 m depth), Soucémarianadin et al. (2018a) compared three different methods used for SOC lability assessment. They showed that Rock-Eval 6 (RE6) parameters were good estimates of the POM-C fraction. The authors conclude that RE6 thermal analysis could therefore be a fast and cost-effective alternative to more time-consuming methods used in SOC pool determination, and may be integrated into soil monitoring networks to provide high-throughput information on SOC dynamics.

Soucémarianadin et al. (2018b) aimed at identifying the factors controlling soil organic carbon (SOC) stability using a set of soils from 53 French Level II sites. They assessed the effects of soil depth (up to 1 m), soil class (dystric Cambisol; eutric Cambisol; entic Podzol), vegetation types (deciduous; coniferous) and climate (continental influence; oceanic influence; mountainous influence) on SOC stability using indicators derived from laboratory incubation, physical fractionation and thermal analysis. In addition to the expected effect of depth, they found a noticeable effect of soil class on SOC stability and suggest that environmental variables should be included when mapping climate regulation soil service.

Johnson et al. (2018) studied the response of soil solution chemistry in mineral horizons of European forest soils to decreasing acid deposition. Trends in pH, acid neutralizing capacity (ANC), major ions, total aluminium (Al_{tot}) and dissolved organic carbon were determined for the period 1995–2012 on plots with at least 10 years of observations from the ICP Forests monitoring network. There was a large decrease in the concentration of sulphate (SO_4^{2-}) in soil solution; over a 10-year period (2000–2010) SO_4^{2-} decreased by 52% at 10–20 cm and 40% at 40–80 cm. Nitrate was unchanged at 10–20 cm but decreased at 40–80 cm. The decrease in acid anions was accompanied by a large and significant decrease in the concentration of the nutrient base cations: calcium, magnesium and potassium and Al_{tot} over the entire dataset. The response of soil solution acidity was non-uniform at the two soil depths. The authors state that their results suggest a long-time lag between emission abatement and changes in soil solution acidity.

To study the impacts of deposition and climate change on soil properties and to describe future projections, Holmberg et al. (2018) calibrated and ran the soil dynamic model VSD+ at 26 European forested study sites, including sites of ICP Forests and ICP Integrated Monitoring. Simulating key soil properties (soil solution pH (pH), soil base saturation (BS) and soil organic carbon and nitrogen ratio (C:N)) under projected deposition of N and S, and climate warming until 2100, they found that future soil conditions improved under the projected decrease in deposition and current climate conditions with higher pH, BS and C:N at 21, 16 and 12 of the sites, respectively. When climate change was included in the scenario analysis, the variability of the results increased. Climate warming resulted in higher simulated pH in most cases, and higher BS and C:N in roughly half of the cases. Especially the increase in C:N was more marked with climate warming.

Tree and forest condition

With the start of the ICP Forests programme in 1985 and the establishment of the 16x16 km grid of Level I monitoring plots across Europe, tree condition has been the first transnational survey conducted and it has since then been annually assessed.

Tree crown condition for Italian Level I plots were evaluated by Bussotti et al. (2018) for the period 1997 to 2014. Tree crown defoliation was found to be species specific and followed the geographical distribution of the main forest types (i.e. high defoliation in *Castanea sativa* Mill. in north-western Italy and *Pinus sylvestris* L. in the southern Alpine belt and North-West Italy). In general, crown defoliation was higher in broadleaved species than in coniferous tree species (in the period 1997–2014, the mean percentage of trees with defoliation > 25% was 39.7 % for broadleaves and 24.1 % for conifers). Crown defoliation of Norway spruce in 2014 and change in defoliation intensity between 2006 and 2011 showed a slight but significant positive correlation with increasing local tree diversity in a tree's neighborhood.

Crown condition and the phosphorus and nitrogen status in the soil and needles in young spruce stands in the Lužické, the Jizerské and the Orlické Mountains of Czechia were evaluated for the reference period 2004–2014 by Novotny et al. (2018). The defoliation in spruce was significantly higher at the beginning than it was at the end of the reference period when it ranged between 15 and 20% because of extensive damage by air pollution in the 1980s and 1990s and the fungus *Ascocalix abietina*. An important role in the disturbance of the nutritional balance in all three mountain ranges is the continuous deposition of nitrogen entering the forest ecosystems and the associated acidification of soils. Ongoing nitrogen deposition, soil acidification, decreasing availability of P and rising N/P ratios in the needles all indicate the nutritional problems of P in spruce stands on most of the monitored areas in the Lužické and the Jizerské Mountains in future.

Using crown defoliation data of more than 100 ICP Forests sites, Sousa-Silva et al. (2018) found a progressive shift from a negative to a positive effect of tree species richness on forest vitality. The observed drought-induced tipping point in the balance of net interactions, from competition to facilitation, has never been reported from real ecosystems outside experimental conditions. The strong temporal consistency of the findings with increasing drought stress emphasizes its climate change relevance. Furthermore, higher species diversity has been found to reduce the severity of defoliation in the long term. Their results confirm the greater resilience of diverse forests to future climate change-induced stress.

Fructification, tree growth, and mortality

Based on a European dataset of 321 sites, Hacket-Pain et al. (2018) used tree-ring chronologies and data on annual reproductive effort of *Fagus sylvatica* for the period 1901–2015 to characterize relationships between climate, reproduction and growth. Their results highlight that variable allocation to reproduction is a key factor for growth in this species, and that high reproductive effort (i.e., mast years) is associated with stem growth reduction and previous summer temperature, creating lagged climate effects on growth. However, it can be highly variable and influenced by climate change.

Lebourgeois et al. (2018) aimed at identifying which drivers control the spatio-temporal variability of fruit production in three major European temperate deciduous tree species: *Quercus robur*, *Quercus petraea*, and *Fagus sylvatica*. They analysed the relationship between fruit production and airborne pollen, carbon and water resources, and meteorological data in 48 French forests over 14 years (1994-2007) and confirm that temperature variables play a major role for both oak and beech. In oak, acorn production was mainly related to temperature conditions during the pollen emission period, supporting the pollen synchrony hypothesis. In beech, a temperature signal over the two previous years determined the airborne pollen load. In general, fruit production in *Quercus* and *Fagus* was related to climate, carbon inputs and airborne pollen through strongly non-linear, genus-specific relationships. Their results indicate that fruit production seemed highly variable and rather poorly explained by empirical models.

Mast seeding, i.e. the synchronised occurrence of large amounts of fruits and seeds at irregular intervals, is a reproductive strategy in many wind-pollinated species. Determining mast occurrence in five different tree species, Nussbaumer et al. (2018) studied the impact of weather cues and resource dynamics on ICP Forests Level I and Level II plots across Europe. At European scale, important weather cues for beech mast years (MYs) were a cold and wet summer two years before a MY, a dry and warm summer one year before a MY and a warm spring in the MY. For spruce, a cold and dry summer two years prior to a MY and a warm and dry summer in the year before the MY showed the strongest associations with the MY. For oak, high spring temperature in the MY was the most important weather cue. Fruiting levels were high in all species two years before the MY and in the oak species and pine also high one year before the MY.

Koulelis et al. (2018) developed diameter and height functions for three native Greek tree species (Bulgarian fir, European beech and Hungarian oak) at three permanent ICP Forests Level II plots. The Sigmoidal-Chapman model provided the most accurate estimations for diameter and height growth for these species at those sites. In addition, the model showed satisfying results after its implementation for the coming years. In general, the use of these height-diameter functions in future monitoring will be significant, considering that future challenges require more information on Mediterranean forest resources.

Using satellite data, Senf et al. (2018) analysed trends in forest canopy changes between 1984 and 2016 over more than 30 Mill. hectare of temperate forests in Europe, based on a unique dataset of 24,000 visually interpreted spectral trajectories from the Landsat archive. They found that on average 0.79% of the forest area was affected by natural mortality or harvesting annually. Loss of canopy increased by +2.40% year^{-1}, doubling the forest area affected by mortality or harvesting since 1984. Areas experiencing low-severity mortality/harvesting increased more strongly than areas affected by stand-replacing mortality/harvesting events. Changes in climate and land-use are likely causes of large-scale forest mortality/harvesting increase. Their findings reveal profound changes in recent forest dynamics with important implications for carbon storage and biodiversity conservation.

Forest biodiversity

Alekseev (2018) conducted a biological diversity census of understory species, coarse woody debris and a soil inventory as a case study for assessing forest ecosystem biodiversity on the Karelian Isthmus, Russia, to be used as thresholds to evaluate further changes in biodiversity. Site selection was based on the regular grid of sample plots from the ICP Forests programme and proved to be effective to provide statistically reliable data for different plant biodiversity characteristics.

Evaluating the impact of wild ungulate populations, Boulanger et al. (2018) compared the temporal variation of the ground vegetation composition inside and outside 82 fenced French Level II plots. Differences were already significant after the investigated 10 years. Outside the fence, forest ungulates (i.e., red and roe deer, wild boars) maintained a higher species richness in the herbaceous layer (+15%), while the shrub layer was 17% less rich, and the plant communities became more light-demanding. Inside the fence, shrub cover increased, often to the benefit of bramble (*Rubus fruticosus* agg.). Among plots, the magnitude of vegetation changes was proportional to deer abundance. In conclusion, ungulates increase plant species richness in those forests but to the benefit of light-demanding ruderal non-forest species.

Climate effects

To understand the role of phenology in ecosystem CO_2 exchange processes in European forests, Han et al. (2018) used a process-based ecosystem simulation model, BIOME-BGC, to investigate spatio-temporal variation in phenology and its impacts on carbon fluxes in European forests during 1999–2013. They used 110 ICP Forests Level II plots from seven countries to analyze phenological trends. The modelled trend towards longer growing seasons and an earlier start of the season because of climate change is followed by a lowered carbon sequestration potential in European forest, which could be explained by the opposing effect of enhanced heterotrophic respiration directly induced by the extension of the growing season.

Rebetez et al. (2018) describe meteorological measurements taken since 1997 at 16 ICP Forests Level II sites across the complex topography of Switzerland, both under the canopy and in the open-field nearby. The data offer detailed comparisons of deciduous, mixed, and coniferous forest microclimatic conditions with standard meteorological conditions in the open-field. Contrary to the open-field stations, those under the canopy do not fully correspond to the WMO criteria.

Advancing methodologies

The ICP Forests Manual is revised every five years and new methodologies are always taken into consideration. In a study by Dambrine et al. (2018), sampling snow cores to analyze the relative effects of N deposition on remote alpine ecosystems proved to be efficient and the authors recommend it to be applied over the entire Alpine massif or other mountainous ranges. They compared the snowpack composition at a fixed elevation (2000 m a.s.l.) and observed a clear gradient of increasing nitrate concentrations from the south to the north of the French Alps. This gradient was less marked for NH_4. When snow concentrations were compared to mean volume-weighted concentrations in bulk precipitation measured at the three alpine monitoring sites of the French Level II network, they showed good agreement. However, altitudinal and latitudinal gradients need to be taken into account.

Kosonen et al. (2018) supported the suitability of mosses as biomonitors by determining total N input from the atmosphere to the ecosystem at 24 sites in Switzerland and comparing this value to the N concentration in two moss species (*Hypnum cupressiforme* Hedw., *Pleurozium schreberi* (Willd. Ex Brid) Mitt.). They showed that including the dry deposition of gases (nitrogen dioxide, nitric acid, ammonia) and aerosols (nitrate, ammonium) can improve the correlation between the N concentration in moss and N deposition, especially at sites with a relatively high ammonia concentration in the air. The particular moss species tested had no influence on the correlation between N in moss and total N deposition.

Barka et al. (2018) describes and compares the remote sensing-based systems for rapid and cost-effective nationwide assessments of forest health in Czechia and Slovakia after using ICP Forests data from visual damage assessments for ground-truthing. Methodologies are based on Landsat and/ or Sentinel-2 data, thus, strongly depend on the quality of input satellite data, but are highly accurate and cost-efficient and can be fast and automatized. Weaknesses include, for example, high computational demands for production cloud free mosaics, the inability to identify initial phases of forest health decline, the exclusion of stands older than 80 years (in Czechia) and the inability to differentiate between harvested and severely damaged stands (in Slovakia).

The clumping index (CI) is a measure of foliage aggregation relative to a random distribution of leaves in space. The CI can help with estimating fractions of sunlit and shaded leaves for a given leaf area index (LAI) value. Both the CI and LAI can be obtained from global Earth Observation data from sensors such as the Moderate Resolution Imaging Spectrometer (MODIS). Pisek at al. (2018) examined the synergy between a MODIS-based CI and a MODIS LAI product using the theory of spectral invariants, also referred to as photon recollision probability, along with raw LAI-2000/2200 Plant Canopy Analyzer data from 75 sites distributed worldwide across a range of plant functional types. They show that empirically-based CI maps can be integrated with the MODIS LAI product. Their results indicate that it is feasible to derive approximate p-values for any location solely from Earth Observation data. This approximation is relevant for future applications of the photon recollision probability concept for global and local monitoring of vegetation using Earth Observation data.

Forest types classification systems are aimed at stratifying forest habitats. Since 2006, a common scheme for classifying European forests into 14 categories and 78 types (European Forest Types, EFT) exists. Giannetti et al. (2018) present an innovative method and automated classification system that, in an objective and replicable way, can accurately classify a given forest habitat according to the EFT system of nomenclature. A rule-based expert system (RBES) was adopted as a transparent approach after comparison with the well-known RandomForest (RF) classification system. The experiment was carried out based on the information acquired in the field from 2010 ICP Forests Level I plots in 17 European countries. The accuracy of the automated classification is evaluated by comparison with an independent classification of the ICP Forests plots into EFT carried out during the BioSoil project field survey.

New initiatives

An international and interdisciplinary meeting organized by Hartmann et al. (2018) was held in Germany in 2017 to discuss how to improve the detection of global-scale patterns, drivers, and trends of the apparent emergence of widespread tree mortality events in diverse forests around the world. This workshop led to several actions toward the implementation of a formal global initiative. These include: (1) an online metadata collection (http://www.tree-mortality.net/) bringing together multiple-plot networks like ICP Forests or ForestGEO for ground-truthing of remote sensing data. Furthermore, the network (2) envisions a new section of the International Union of Forest Research Organizations (IUFRO), works on (3) developing methods and protocols for monitoring mortality and will present (4) a multidisciplinary strategy paper. In addition, (5) several promising collaborative efforts to share data on forest condition at the global scale have been initiated (e.g. the Global Forest Biodiversity Initiative (GFBI), http://www.gfbinitiative.org/).

List of ICP Forests-related scientific publications (January – December 2018)

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3 PRESENTATIONS AT THE 7TH ICP FORESTS SCIENTIFIC CONFERENCE, RIGA, 22–23 MAY 2018

The 7th ICP Forests Scientific Conference *European forests in a changing environment: Air pollution, climate change and forest management* was hosted by the Ministry of Agriculture of the Republic of Latvia and the Latvian State Forest Research Institute (SILAVA) in Riga, 22–23 May 2018, with 84 participants from 26 countries.

After three decades of monitoring by ICP Forests, long-term data series provide a unique asset for the evaluation of status, trends and processes in European forest ecosystems. Hence, the 7th ICP Forests Scientific Conference offered the possibility to present results from all forest related monitoring and research infrastructures.

The conference addressed scientists and experts from ICP Forests, the wider UNECE community under and beyond the Working Group on Effects (WGE), partners and stakeholders, and interested scientists and experts from related fields. Especially, researchers using ICP Forests data in their projects, evaluations, and modelling exercises were invited.

The main topics were:

- Changes in ecosystem processes in forests under various management regimes
- Time series on forest ecosystem processes and their (inter-) relationships
- Climate change adaptation of forests and their contribution to climate change mititgation
- Research data management

The following list includes all oral and poster presentations at the 7th ICP Forests Scientific Conference. All conference abstracts are available from the ICP Forests website[1].

Adame P, Cañellas I, Gonzalez AI, Guerrero S, Belen Torres M, Alberdi I [Poster] Litter carbon stock variability in the Spanish forest types

Baltrėnaitė E, Baltrėnas P, Lietuvninkas A [Poster] Processes and barriers involved in the contaminant mobility reduction through the life cycle of a tree

Boulanger V, Nicolas M, et al. [Presentation] Ungulates increase forest plant species richness to the benefit of non-forest specialists

Brandl S, Burggraef L, Falk W [Keynote] Effects of climate and management on productivity and mortality of European beech and Norway spruce in Europe

Braun S, Schindler C, Rihm B [Presentation] Ecological conclusions from long-term growth series of beech and Norway spruce in Switzerland

Cailleret M, Haeni M, Ferretti M, Gessler A, Rigling A, Prescher A-K, Simpson D, Schaub M et al. [Presentation] Sensitivity of mean ozone concentration, AOT40, and POD1 estimates to different sources for ozone, climate and vegetation data

Calatayud V, Shang B, Gao F, Feng Z [Poster] Current ambient and elevated ozone effects on poplar: a global meta-analysis and response relationships

Canullo R, Chelli S, Ottaviani G, Simonetti E, Wellstein C, Carnicelli S, Adreetta A, Puletti N, Bartha S, Campetella G [Presentation] Drivers of plant functional traits in understory communities of Italian forests

Češljar G, Đorđević I, Rakonjac L, Stefanović T, Gagić-Serdar R, Momirović N [Poster] Trends of average tree defoliation on sample plots Level I in Serbia

Ciceu A, Dobre A, Leca S, Chivulescu S, Popa I, Badea O [Poster] Crown defoliation effect on tree growth recorded at the Romainian Level II

Ciuvat A-L, Dinca L, Enescu R-E, Crisan E-V [Poster] Influence of climatic changes on the foliar nutrition of the main forest species found in ICP Level II core plots in Romania

Clarke N, Timmermann V, Andreassen K, Nordbakken J-F [Poster] One size does not fit all: climate, N deposition and management of forest biomass removal in Norway

Cutini A, Gottardini E, Bagella S, Fratini R, Patteri G, Ciucchi B, Bertini G, Chianucci F, Fabbio G [Poster] Shaping future forestry for sustainable coppices in southern Europe: the contribution of LIFE FutureForCoppiceS project

Enescu II, Plattner G-K, Haas-Artho D, Ferretti M, Lehning M, Steffen K [Poster] The conceptual framework of the WSL environmental data portal EnviDat

Enescu II, Plattner G-K, Schaub M, Meile R, Gessler A, Brändli U-B, Hägeli M, Ferretti M, Lehning M, Steffen K [Presentation] Forest data integration in the WSL environmental data portal EnviDat

Ferretti M, Cherubini P, Chiarucci A, Tognetti R [Keynote] Changing perspective – more ecology is necessary for air pollution studies

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

García-Gómez H, Izquieta-Rojano S, Aguillaume L, González-Fernández I, Valiño F, Santamaría JM, Elustondo D, Àvila A, Rábago I, Alonso R, Bermejo-Bermejo V [Presentation] Deposition of nitrogen in Mediterranean forests of *Quercus ilex*: significance of dry deposition

García-Gómez H, Vivanco MG, Theobald MR, Garrido JL, Prank M, Aas W, Andersson C, Bessagnet B, Bianconi R, Brandt J, et al. [Poster] Eutrophication risk of European forests: a first approximation using empirical critical loads and atmospheric chemical models

Gottardini E, Cristofolini F, Cristofori A, Ferretti M [Presentation] Ozone removal by Norway spruce forests: a case study in Trentino, North Italy

Iacoban C, Thimonier A, Waldner P, Meusburger K, Guiman G, Bragă C, Voiculescu I, Curcă M, Leca S [Presentation] Trends of pollutants concentrations and fluxes in depositions and soil solution in Romania (1998-2016)

Ingerslev M, Vesterdal L, Bjerager PER, Gundersen P [Poster] Time trends in nitrogen, and sulfur throughfall fluxes and soil solution concentrations

Izquieta-Rojano S, López-Aizpún M, Irigoyen JJ, Santamaría JM, Santamaría C, Lasheras E, Ochoa-Hueso R, Elustondo D [Poster] Eco-physiological response of *Hypnum cupressiforme* Hedw. to increased atmospheric ammonia concentrations in a forest agrosystem

Jochheim H, Brunet-Navarro P, Muys B [Presentation] Mitigation potential of forest management and wood products use – Simulation study for intensive monitoring plots of Brandenburg, Germany

Jochheim J, Wirth S, Paulus S, Maier M [Poster] Quantification of soil respiration and vertical partitioning of soil CO_2 production in a beech and a pine forest stand in the Northeast German Lowland

Kirchner T, Wohner C, Peterseil J, Ryl R [Presentation] ICP Forests & LTER – a first handshake between data infrastructures

Kreslina V, Lazdina D [Poster] Changes in vascular plant communities in the third to fifth year in an experimental tree trial on arable land

Lazdina D, Bambe B, Bebre I [Poster] Development of reforested stand on former peat mining area - a case study

López-Aizpún M, Arango-Mora C, Santamaría C, Lasheras E, Santamaría JM, Ciganda V, Cárdenas L, Elustondo D [Poster] Atmospheric ammonia concentration modulates soil enzyme and microbial activity in an oak forest soil microbial biomass

Lupikis A [Presentation] Filling the gaps of modelling of the soil carbon cycling through better forest litter input data [Poster] Atmospheric ammonia concentration modulates soil enzyme and microbial activity in an oak forest soil microbial biomass

Markovic M, Rajkovic S, Rakonjac L [Poster] Biological measure in seedlings protection

Meesenburg H, Ahrends B, Fleck S, Willig J, Wagner M [Presentation] Specific Leaf Area reconstruction may provide the missing link between litterfall and Leaf Area Index

Meusburger K, Thimonier A, Graf Pannatier E [Poster] Trends in dissolved organic carbon in soil solution at Swiss Level II plots

Michopoulos P, Bourletsikas A, Kaoukis K, Samara C, Grigoratos T [Poster] Nutrients in litterfall and forest floor in two adjacent forest ecosystems in the area of the mountain Ossa in northeastern Greece

Nieminen TM, Merilä P, Ukonmaanaho L [Presentation] Comparison of soil solution sampling techniques in a Norway spruce forest in Finland

Novotný R, Lomský B, Šrámek V [Poster] Trends in tree nutrition within the ICP Forests Level II plots in the Czech Republic

Pavlović RŽ, Popović B, Blagojević B [Poster] Poplar cuttings under drought conditions induced with PEG6000

Pollastrini M, Iacopett G, Bussotti F, Selvi F, Maggino F [Presentation] Relationships between crown defoliation and tree diversity depend on the environmental context

Potočić N, Seletković I, Jakovljević T, Radojčić Redovniković I, Ognjenović M [Presentation] The use of monitoring data for improving the management of pedunculate oak (*Quercus robur* L.) stands in Spačva basin, Croatia

Puhlmann H, Sucker C, Hölscher A [Poster] Critical nitrogen loads for N sensitive forest communities

Rajkovic S, Markovic M, Rakonjac L [Poster] Ozone injury - Kopaonik - Level II

Rodeghiero M, Vesterdal L, Marcolla B, Vescovo L, Aertsen W, Martinez C, Di Cosmo L, Gasparini P, Gianelle D [Presentation] Soil nitrogen explanatory factors across a range of forest ecosystems and climatic conditions in Italy

Russ A, Riek W, Kallweit R, Jochheim H, Lüttschwager D, Hannemann J, Grünwald T, Barth R, Becker F [Presentation] Water balance of selected sites and tree species – Retrospect of 20 years of monitoring in the federal state of Brandenburg (Germany)

Salehi M, Walthert L, Zimmermann S, Brunner I, Thimonier A [Presentation] Leaf nutrients and leaf morphological traits in beech stands across a water availability gradient in Switzerland

Salemaa M, Merilä P, Hamberg L, Kaarlejärvi E [Presentation] Functional significance of nitrogen productivity of boreal forest plants

Sase J, Morohashi M, Takahashi M, Saito T, Yamashita N, Inomata Y, Ohizumi T, Shin K-C, Tajasu I, Nakano T [Poster] Multi-isotopic approach for monitoring on atmospheric deposition in forests in Japan

Schleppi P, Baer T [Poster] Nitrate leaching and soil acidification in a long-term N-addition experiment to a sub-alpine forested catchment on Gleysol

Sidor CG [Poster] Phenological observations at 6 species of trees in the growing seasons 2014, 2015 and 2016 from Level II ICP Forests Romanian Network

Sousa-Silva R, Verheyen K, Ponette Q, Bay E, Laurent C, Sioen G, Titeux H, Vanhellemont M, Buys B [Presentation] The impact of forest diversity on tree growth and recovery to drought

Stakėnas V, Kulbokas G, Žemaitis P, Varnagirytė-Kabašinskienė I, Araminienė V [Presentation] Changes of deciduous tree species areas during the last decades in Lithuania

Straupe I, Pilecka J, Grinfelde I, Purmalis O, Rums O [Poster] The assessment of anthropogenic air pollution in urban ecosystem using lichenoindication and snow samplings

Tedersoo L [Poster] Mycorrhizal types differ in ecophysiology and ecosystem functioning

Thomsen IM, Krag MM, Bjerager PER [Presentation] Phenology observations in beech and oak by daily photos: experiences from Denmark

Tonteri T, Salemaa M, Hallikainen V, Rautio P, Merilä P, Tolvanen A [Presentation] Declining macrolichens respond to forest management in boreal forests

Trotsiuk V, QUPFiS team [Presentation] Quantifying, Understanding and Predicting Forest growth In Switzerland QUPFiS – a novel analytical pipeline, leveraging a Swiss network of long-term forest-related observations

Ukonmanaaho L, Lindroos A-J, Merilä P, Nieminen TM [Poster] Concentrations of heavy metals in litterfall and soil in boreal forest

Vanguelova E, Benham S, Ashwood F, Brown N, Pinho D, Denman S [Presentation] Links between soil biochemistry and biodiversity with Oak health status

Verstraeten A, Gottardini E, Vanguelova E, Waldner P, Bruffaerts N, Nussbaumer A, Neumann M, Clarke N, Hansen K, Rautio P, Ukonmaanaho L [Presentation] Establishing a link between pollen dispersal, seed production and throughfall dissolved organic carbon (DOC) flux in temperate forests

Wohlgemuth L, Alewell C, Jiskra M, Waldner P, Thimonier A, Meusburger K, Schmitt M, Brunner I [Poster] Approach for a comprehensive assessment of the Hg pool in foliage across Europe

4 ONGOING RESEARCH PROJECTS USING ICP FORESTS DATA / INFRASTRUCTURE

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 46 projects using ICP Forests data and/or infrastructure and that were ongoing for at least one month between January and December 2018. In this period, 15 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
55	Ivan Janssen	University of Antwerp	Effects of phosphorus limitations on Life, Earth system and Society (IMBALANCE-P)	External
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
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
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
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

[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 Air Convention. Different rights and obligations apply to internal vs. external data users.

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
91	Peter Waldner	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	Seed C 2 – Carbon allocation to fruits and seeds in European forests as a function of climate, atmospheric deposition and nutrient supply	Internal
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
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
100	Dr. Michael Kessler	Institute of Systematic and Evolutionary Botany, University of Zurich, Switzerland	Understanding global patterns of fern diversity and diversification	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
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
107	Marcus Schaub	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	PRO3FILE - Predicting Ozone Fluxes, Impacts, and Critical Levels on European Forests	Internal
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
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
121	Francisco Lloret Maya	CREAF	Bioclimatic niche of insect pests and trees in response to climate change	External
123	Arne Verstraeten	Research Institute for Nature and Forest (INBO)	The impact of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) deposition on soil solution DOC and DON	Internal
124	Ralph Martin	University of Freiburg	The Common Crossbill (Loxia curvirostra) within Europe – are call types connected with specific geographical regions?	External
125	Tanja Sanders	Thünen Institute of Forest Ecosystems, Eberswalde	Extending trait-based dynamic global vegetation model (LPJmL-FIT) to temperate forests	Internal

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
126	Joep Langeveld	Utrecht University (department of Geochemistry)	Modeling global carbon flows in groundwater systems	External
127*	Filippo Bussotti	University of Firenze	Linking forest diversity and tree health in Europe	External
128	Yongshuo Fu	University of Antwerp and Beijing Normal University	Understanding tree phenology in relation to climate	External
129*	Tanja Sanders	ICP Forests Expert Panels Growth / Foliar	Relationships between soil-litter-leaf elemental composition and stoichiometry with tree crown condition, health and growth under different climatic and atmospheric pollution status	Internal
130*	Xuanlong Ma	Max-Planck Institute for Biochemistry, Jena, Germany	Remote sensing upscaling biodiversity from ICP Forests Level II using ESA's Sentinels	External
131*	Alessandro Cescatti	Joint Research Centre of European Commission	FOREST@RISK	External
132	Göran Ågren	Swedish University of Agricultural Sciences - Department of Ecology	Multidimensional plant stoichiometry, moving beyond C,N, and P	External
133	Myriam Legay	Office National de Forêts	IKSMAPS: Providing precalculated future distribution maps for the main French forestry species through IKS model - Part 2: development of a silvoclimate service based on the IKS model	External
134*	Marcus Schaub	WSL, Swiss Federal Institute for Forest, Snow and Landscape Research	Forests under stress: understanding how species interact and adjust to climate change	Internal
135*	Anne-Katrin Prescher	Programme Co-ordinating Centre of ICP Forests	Model simulations to disentangle the effects of changes in CO_2, climate and deposition on trends in leaf stoichiometry	Internal
136*	Anne-Katrin Prescher	Programme Co-ordinating Centre of ICP Forests	A simple scheme to represent the effects of litter stoichiometry and soil mineral N availability on microbial decomposition process	Internal
137*	Marco Ferretti	WSL - Chair of ICP Forests	DEFORSCEN - UNDERSTANDING CANOPY DEFOLIATION OF EUROPEAN FORESTS UNDER RECENT CLIMATE CHANGES TO PREDICT FUTURE ADAPTATION SCENARIOS	Internal
142*	Maryam Salehi	WSL, Swiss Federal Institute for Forest, Snow and Landscape Research	Leaf nutrients and leaf morphological traits in European beech stands across a water availability gradient	Internal
143*	Kailiang Yu	ETH Zürich	Spatiotemporal changes in carbon turnover time and its drivers and mechanisms in forests	External
144	Nenad Potočić	Croatian Forest Research Institute	Adaptative capacity of Croatian Mediterranean forests to environmental pressures	Internal

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
145*	Anja Nölte	Faculty of Environment and Natural Resources Albert-Ludwigs-Universität Freiburg, Germany	Management strategies under climate change conditions for overaged coppice forests on steep slopes that have important protective functions	External
146	Yong Pang	Institute of Forest Resource Information Techniques Chinese Academy of Forestry	Growth and Yield Prediction of Larch Plantation at Multi-scales	Internal
147*	Denis Loustau	ICOS , Ecosystem Thematic Centre at INRA, UMR ISPA	Quality checking of ICOS Foliar nutrient analysis	External
148*	Dr. Francesca Pilotto	Department of River Ecology and Conservation, Senckenberg Research Institute	Analysis of biodiversity trends using long-term data	External
150*	Ulf Grandin	Swedish University of Agricultural Sciences Sveriges lantbruksuniversitet (SLU)	Nutrient limitation or enrichment in European forests	Internal
151*	Kevin Van Sundert	University of Antwerp	The challenge of comparing nutrient availability among terrestrial ecosystems – potential of soil-, plant- and remote sensing-based nutrient metrics, and development of a metric for temperate and boreal forests	External
153*	Anne-Katrin Prescher	Programme Co-ordinating Centre of ICP Forests	Calibration and Validation of a litter decomposition model for forest ecosystems	Internal

PART B

REPORTS ON INDIVIDUAL SURVEYS IN ICP FORESTS

5 ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2017

Aldo Marchetto, Peter Waldner, Arne Verstraeten

5.1 Summary

Studying the effects of atmospheric pollution on forest ecosystems requires an evaluation of air quality and of the amount of pollutants carried to the forests by atmospheric deposition, which mainly follows two pathways: wet deposition of compounds dissolved in rain and snow and dry deposition of particulate matter through gravity or filtration, for example by the forest canopy.

Pollutant deposition shows a relatively high local variability, related to the distribution of pollutant sources and the local topography, and in-situ measurement is needed to obtain accurate evaluations and to validate model estimates.

In 2017, the chemical composition of open field bulk and below canopy throughfall deposition was measured at 278 and 297 intensive monitoring (Level II) plots, including data from 27 and 49 plots kindly provided by the Swedish Throughfall Monitoring Network (SWETHRO), respectively.

In this report, we focus on throughfall deposition of acidifying, buffering, and eutrophying compounds.

High throughfall deposition of nitrate was mainly found in Central Europe (Germany, Switzerland, the Czech Republic, Austria and Belgium-Flanders), while for ammonium high deposition was also found in northern Italy, southwestern UK, southern Romania and western Poland. The area of high deposition is smaller for sulphate, including some plots in Hungary, Greece, the Czech Republic, Slovakia, Bulgaria and in Belgium-Flanders near the port of Antwerp. High values in coastal areas are partially due to deposition of marine aerosol, and they are less evident after sea-salt correction.

Calcium, potassium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium throughfall deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in Eastern Europe. The correction for the marine contribution does not affect their spatial pattern. On the contrary, in the case of magnesium, the distribution of the highest values is markedly reduced by the sea salt correction.

Note that the total deposition to the forest can be higher (typically for nitrate and ammonia) or lower (typically for buffering compounds) than the throughfall deposition, due to canopy exchange processes.

5.2 Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large part of them can settle, or be adsorbed to receptor surfaces, or be included in rain and snow and finally reach land surface as wet and dry deposition.

Among these substances, in the last two centuries human activities led to a dramatic increase in the deposition of nitrogen and sulphur compounds.

Sulphur deposition almost completely occurs in the form of sulphate (SO_4^{2-}), deriving from marine aerosol and from the interaction in the atmosphere between water and sulphur dioxide (SO_2) forming sulphuric acid.

SO_2 emission derives from volcanoes, forest fires and the combustion of fossil fuels, mainly sulphur containing coal and oil. Following industrial and economic development, SO_2 emission increased since the early 19th century until the 1980s, causing an increase in the deposition of sulphate and in deposition acidity, which can be partly buffered by the deposition of base cations, mainly calcium (Ca^{2+}) and magnesium (Mg^{2+}).

As a consequence of the implementation of air pollution abatement measures in response to the CLRTAP protocols and of economic transformation, SO_2 emission in the countries participating in ICP Forests markedly decreased in the last decades (EEA 2016) resulting in a downward trend in sulphate deposition and a similar decrease in deposition acidity (Waldner et al., 2014).

Natural sources of reactive nitrogen in the atmosphere are mainly restricted to the decomposition of the nitrogen gas molecule (N_2) during lightning. However, human activities cause the emission of a large amount of nitrogen oxides (NO_x), released during combustion processes, and of ammonia (NH_3) deriving from agriculture with high life stocks. They are found in atmospheric deposition in the form of nitrate (NO_3^-) and ammonium (NH_4^+).

N compounds have two effect on the ecosystems: they are important plant nutrients with strong effects on plant metabolism (e.g., Silva et al. 2015), all forest processes (e.g. Meunier et al., 2016) and biodiversity (e.g., Bobbink et al., 2010), but they can also reinforce soil acidification (Bobbink and Hettelingh, 2011).

Emission and deposition of both sulphur and inorganic nitrogen are recently decreasing, but the trend for nitrogen is less evident than for SO_4^{2-}(Waldner et al.2014; EEA 2016).

5.3 Materials and methods

Atmospheric throughfall and bulk deposition is collected in the ICP Forests intensive monitoring (Level II) plots, under tree canopy (throughfall samplers) and in a nearby clearance (open field samplers, Fig. 5-1), respectively. The latter samplers are intended to estimate the intensity of wet deposition, i.e. the amount of pollutants carried by rain and snow. The former samplers are intended to estimate total deposition, including dry deposition due to particulate matter collected by the tree canopy.

However, a tree canopy interacts with atmospheric deposition, for example by the uptake of ammonium ions, nitrification by microorganisms inhabiting leaves and the release of potassium, magnesium and calcium ions and organic compounds, affecting the composition of throughfall deposition.

In the case of beech, a significant component of atmospheric deposition captured by the tree crown flows along the smooth bark and the tree trunks, and is therefore sampled by stemflow collectors installed on beech plots.

Sampling, analysis and quality control procedures are harmonized on the basis of the ICP Forests Manual (Clarke et al. 2016). Quality control and assurance include laboratory ring tests, the use of control charts and performing conductivity and ion balance checks on all samples in each laboratory (König et al. 2010). In calculating ion balance, the charge of organic compounds was considered proportional to the dissolved organic carbon (DOC) content following Mosello et al. (2005, 2008).

Figure 5-1: Throughfall and stem flow collectors on Level II plot in Wijnendale forest, Belgium.

In this report, we consider the 2017 yearly throughfall deposition, collected in 248 ICP Forests Level II plots and 49 SWETHRO plots.

Ten plots were excluded because the duration of sampling covered less than 90% (329 days) of the year, and 78 other plots were marked as “not validated” because the conductivity check was passed for less than 30% of the analysis of the year. Ammonium deposition reported by 2 laboratories for 17 plots, and Calcium deposition reported by one laboratory for 14 plots were not validated as those laboratories did not pass the Working Ring Test minimum quality requirement.

As the deposition of marine aerosol represents an important contribution to the total deposition of sulphate, calcium and magnesium, a sea-salt correction was applied, subtracting from the deposition fluxes the marine contribution, calculated as a fraction of the chloride deposition according to the ICP Modelling & Mapping Manual (CLRTAP 2004).

5.4 Results

The uneven distribution of emission sources and receptors and the complex orography of part of Europe result in a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in throughfall deposition arise. In the case of nitrate, high throughfall deposition was mainly found in Central Europe: Germany, Switzerland, the Czech republic, Austria and Flanders, while values below 4 kg N ha^{-1} y^{-1}, were mainly found in Finland, Sweden, Norway, Hungary, Bulgaria, Romania, Latvia and Estonia (Fig. 5-2).

The Central European area of high ammonium throughfall deposition is larger, also including North Italy, southwest UK, south Romania and west Poland (Fig. 5-3). Values below 4 kg N ha^{-1} y^{-1}, were found again in Norway, Sweden, Finland, Bulgaria, Latvia and Estonia, but also in parts of France, Austria and Slovakia.

The area with higher throughfall deposition of sulphate is smaller than for the nitrogen compounds (Fig. 5-4), including some plots in the Czech republic, Slovakia, Hungary, Bulgaria, Greece and in Flanders near the port of Antwerp. The influence of marine aerosol was relevant in sites with intermediate sulphate deposition in coastal areas, where the correction for sea-salt contribution led to low deposition values (Fig. 5-5) Values below 4 kg S ha^{-1} y^{-1} were mainly found in Norway, Finland, Sweden, UK, Estonia, Latvia, Switzerland and Austria.

Calcium and magnesium are also analyzed in the ICP Forests deposition monitoring network, as their deposition can buffer the acidifying effect of other compounds in atmospheric deposition, and can decelerate or prevent soil acidification. High values of calcium deposition are mostly reported in Southern Europe (Spain, Italy, Greece, Slovenia) (Fig. 5-6). The correction for the marine contribution does not affect their spatial pattern and gives only minor changes in throughfall deposition (Fig. 5-7).

On the contrary, in the case of magnesium, the distribution of the highest values, including a large portion of Southern and Central Europe (Fig. 5-8), is markedly reduced by the sea salt correction (Fig. 5-9).

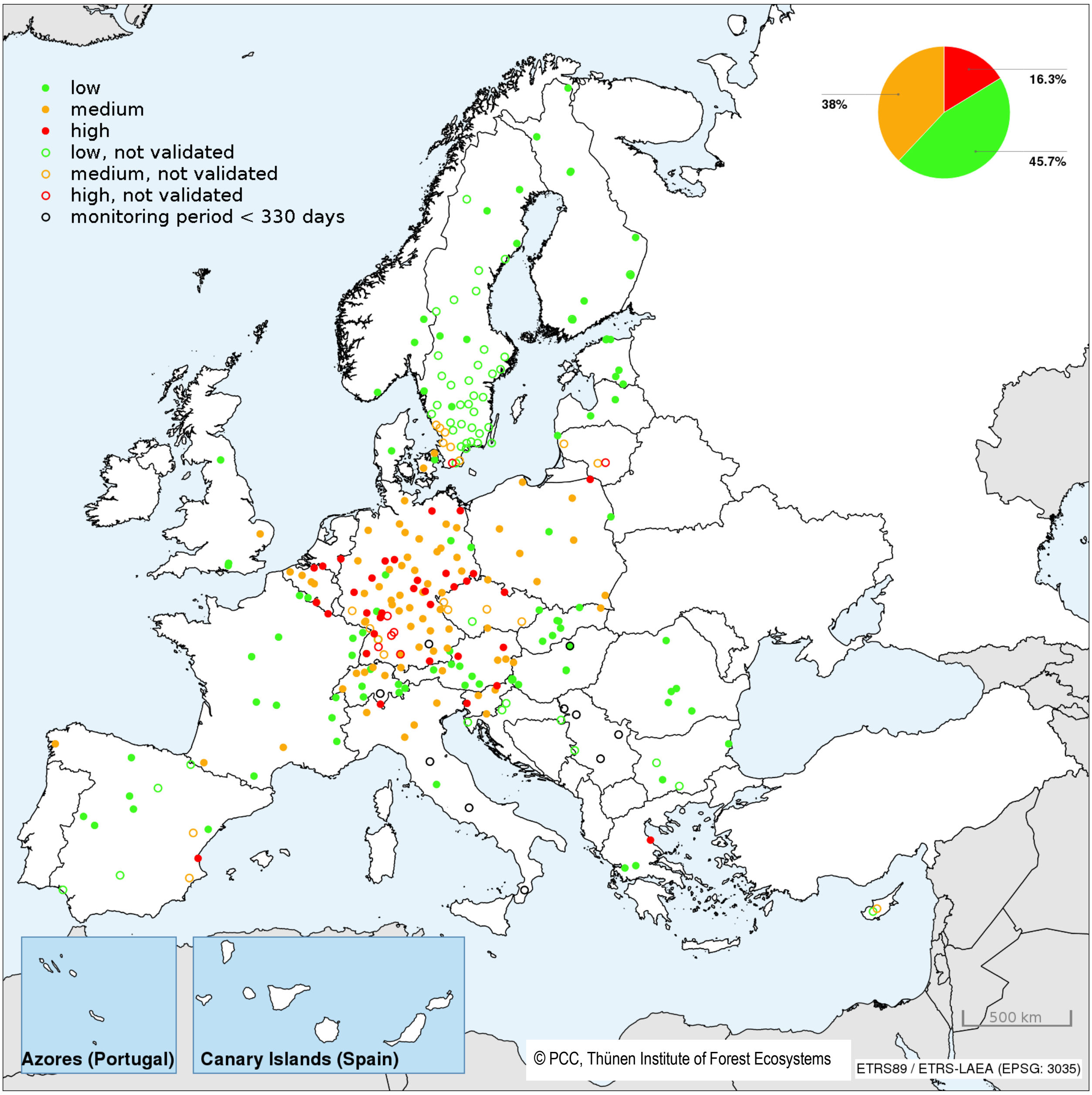

Figure 5-2: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–4.0 kg NO_3^--N ha^{-1} yr^{-1}), medium (>4.0–8.0 kg NO_3^--N ha^{-1} yr^{-1}), high (>8.0 kg NO_3^--N ha^{-1} yr^{-1}).

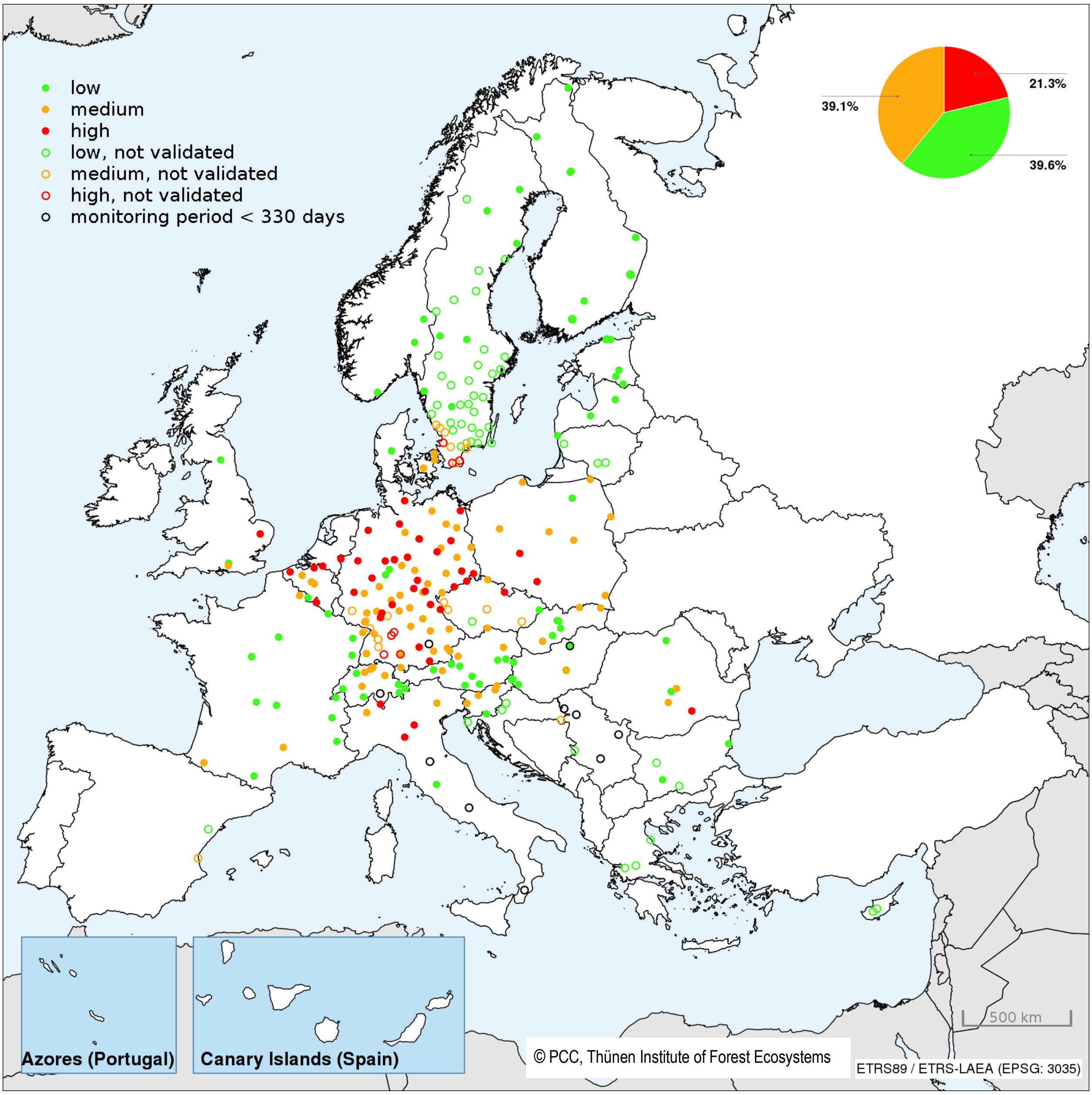

Figure 5-3: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–4.0 kg NH_4^+-N ha^{-1} yr^{-1}), medium (>4.0–8.0 kg NH_4^+-N ha^{-1} yr^{-1}), high (>8.0 kg NH_4^+-N ha^{-1} yr^{-1}).

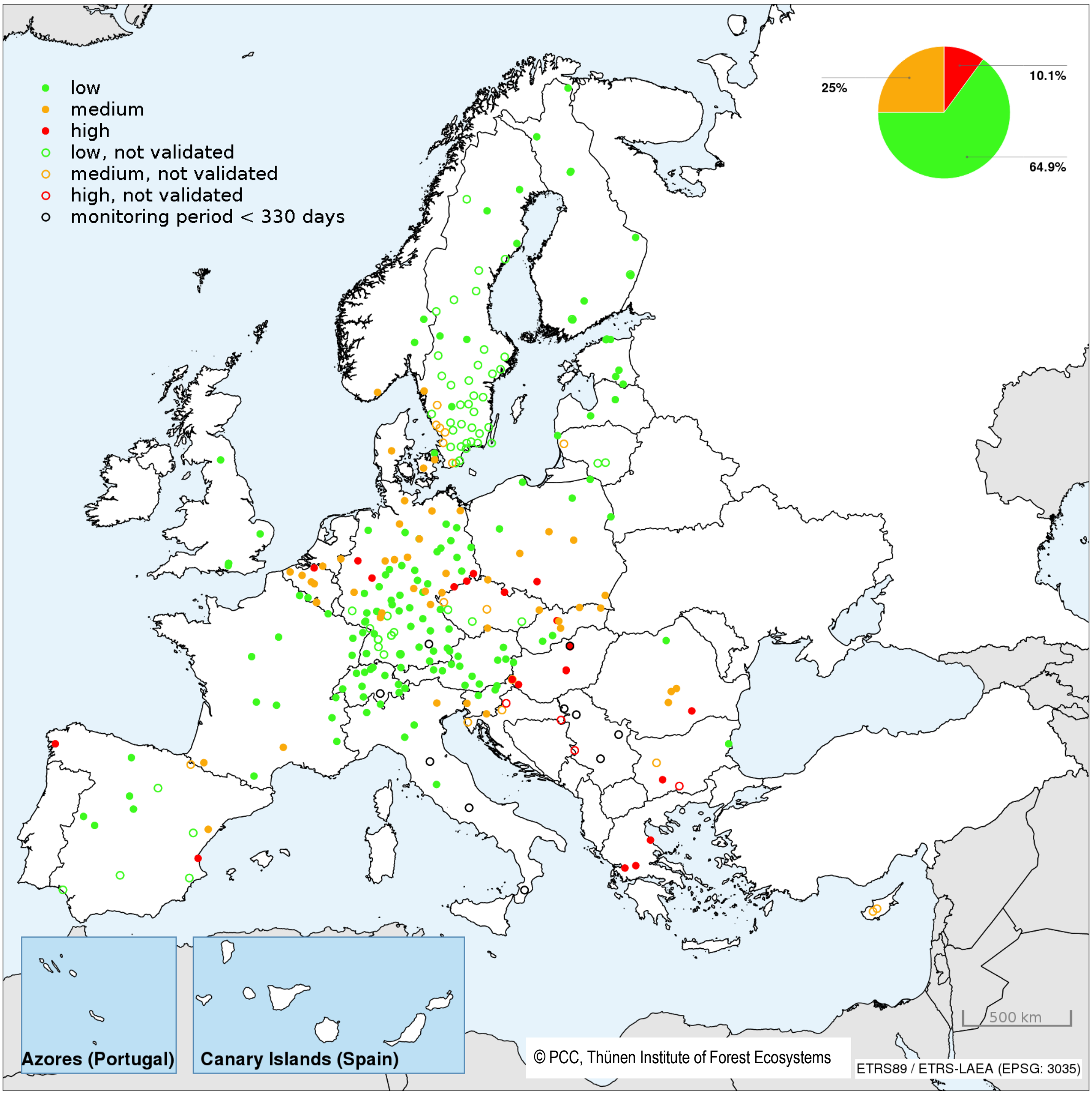

Figure 5-4: Throughfall deposition of sulfate-sulfur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–4.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), medium (>4.0–8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), high (>8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}).

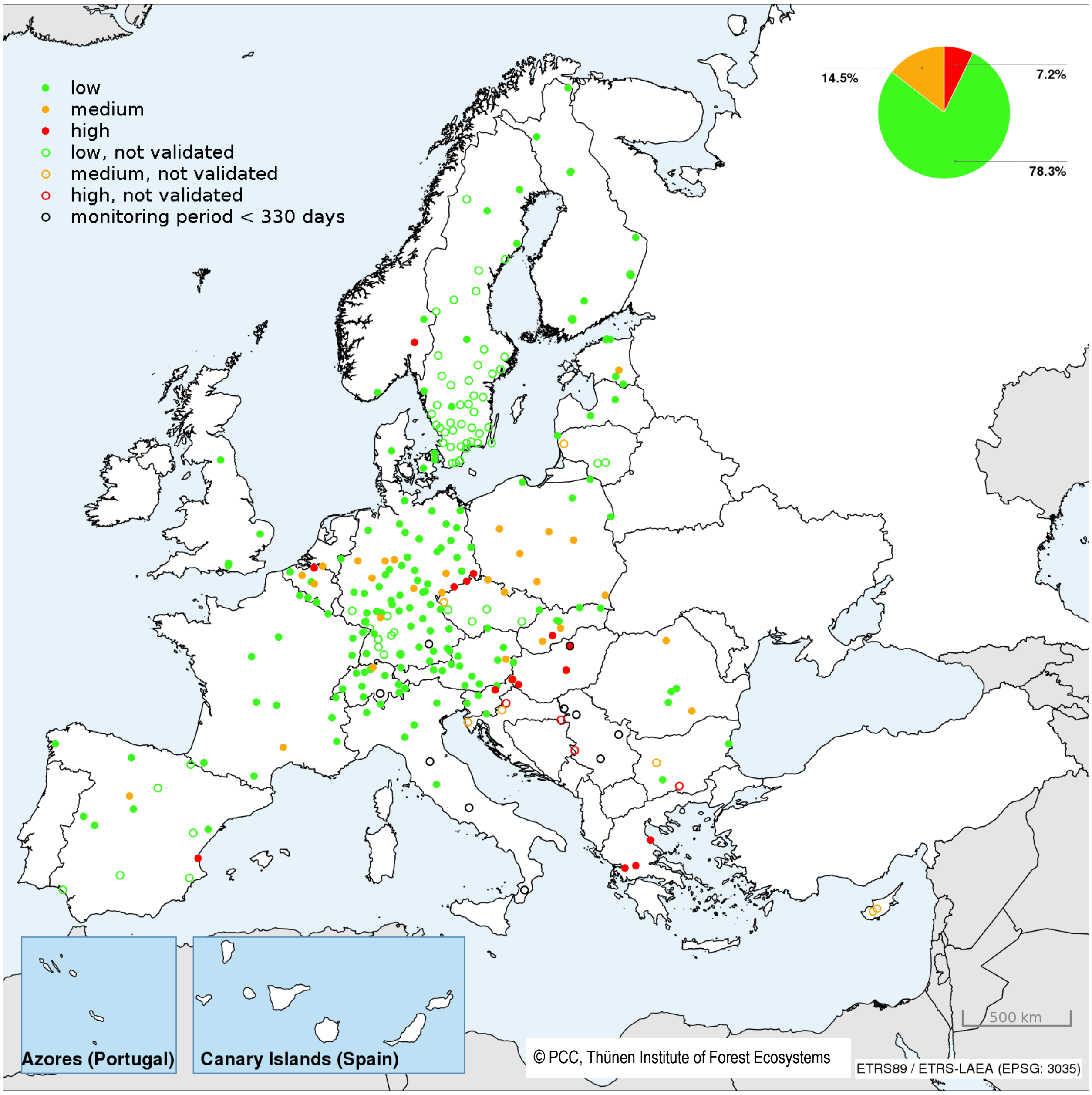

Figure 5-5: Throughfall deposition of sea-salt corrected sulfate-sulfur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–4.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), medium (>4.0–8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), high (>8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}).

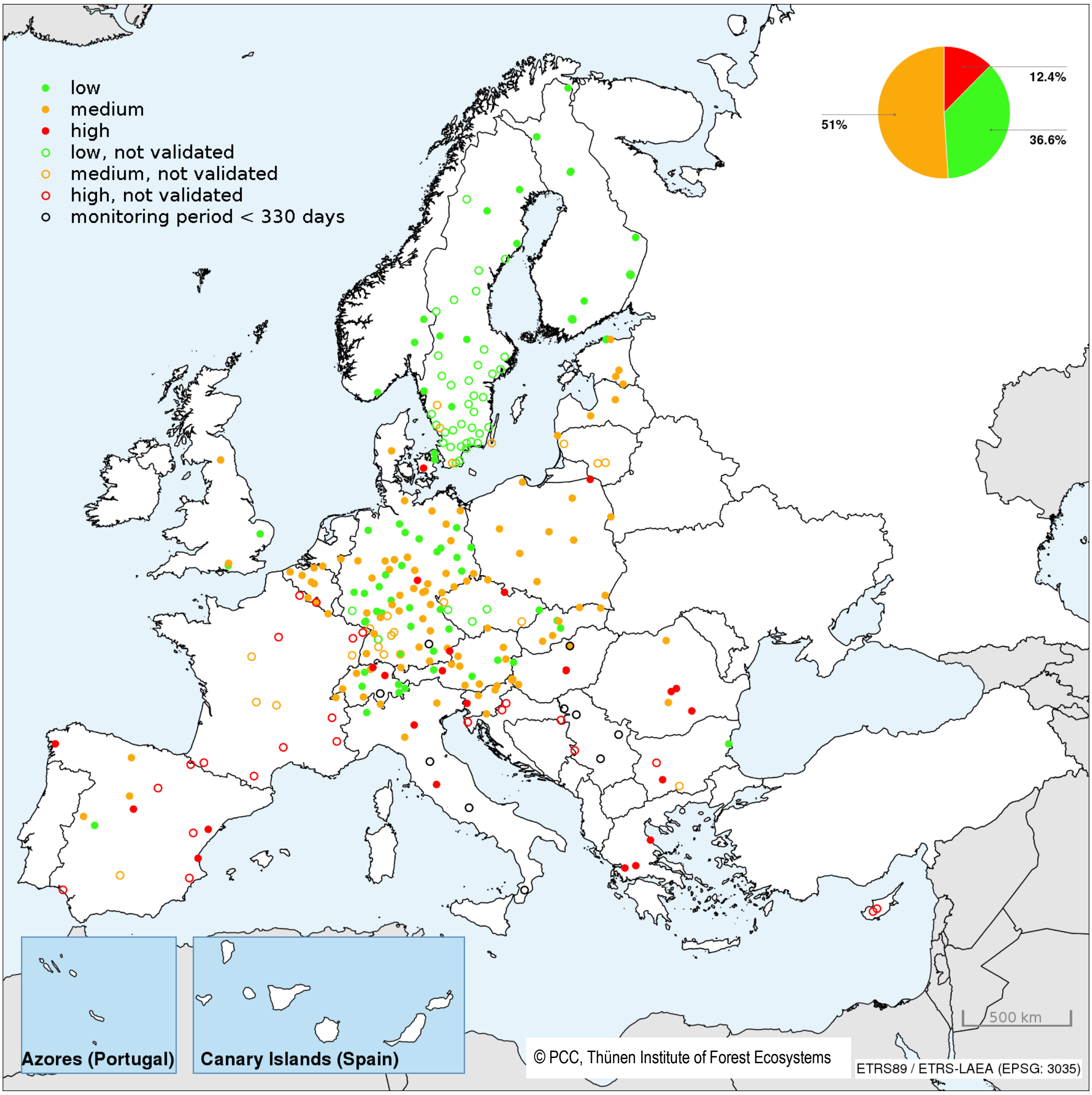

Figure 5-6: Throughfall deposition of calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–5.0 kg Ca^{2+} ha^{-1} yr^{-1}), medium (>5.0–10.0 kg Ca^{2+} ha^{-1} yr^{-1}), high (>10.0 kg Ca^{2+} ha^{-1} yr^{-1}).

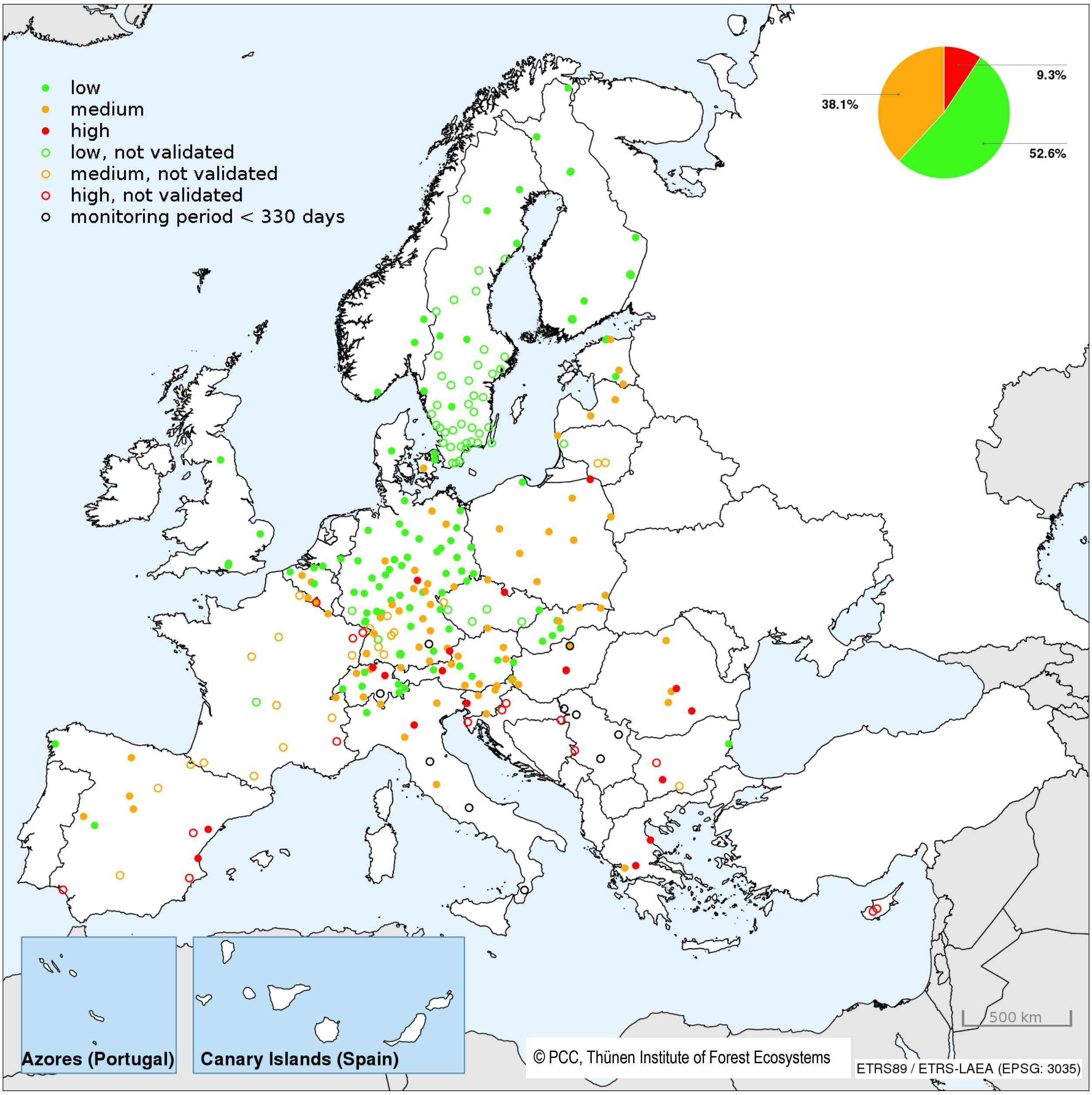

Figure 5-7: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–5.0 Ca^{2+} ha^{-1} yr^{-1}), medium (>5.0–10.0 kg Ca^{2+} ha^{-1} yr^{-1}), high (>10.0 kg Ca^{2+} ha^{-1} yr^{-1}).

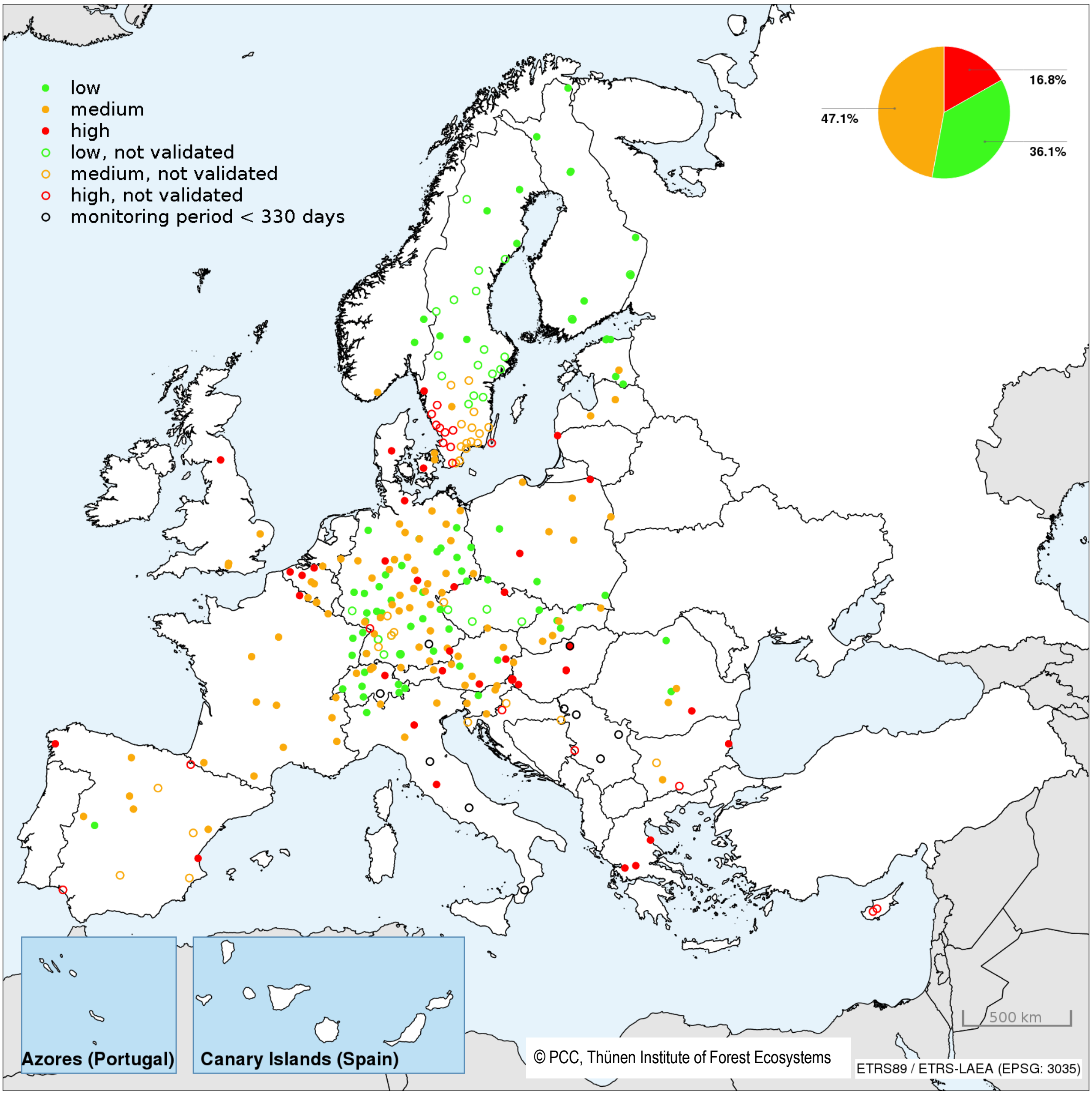

Figure 5-8: Throughfall deposition of magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–1.5 kg Mg^{2+} ha^{-1} yr^{-1}), medium (>1.5–3.0 kg Mg^{2+} ha^{-1} yr^{-1}), high (>3.0 kg Mg^{2+} ha^{-1} yr^{-1}).

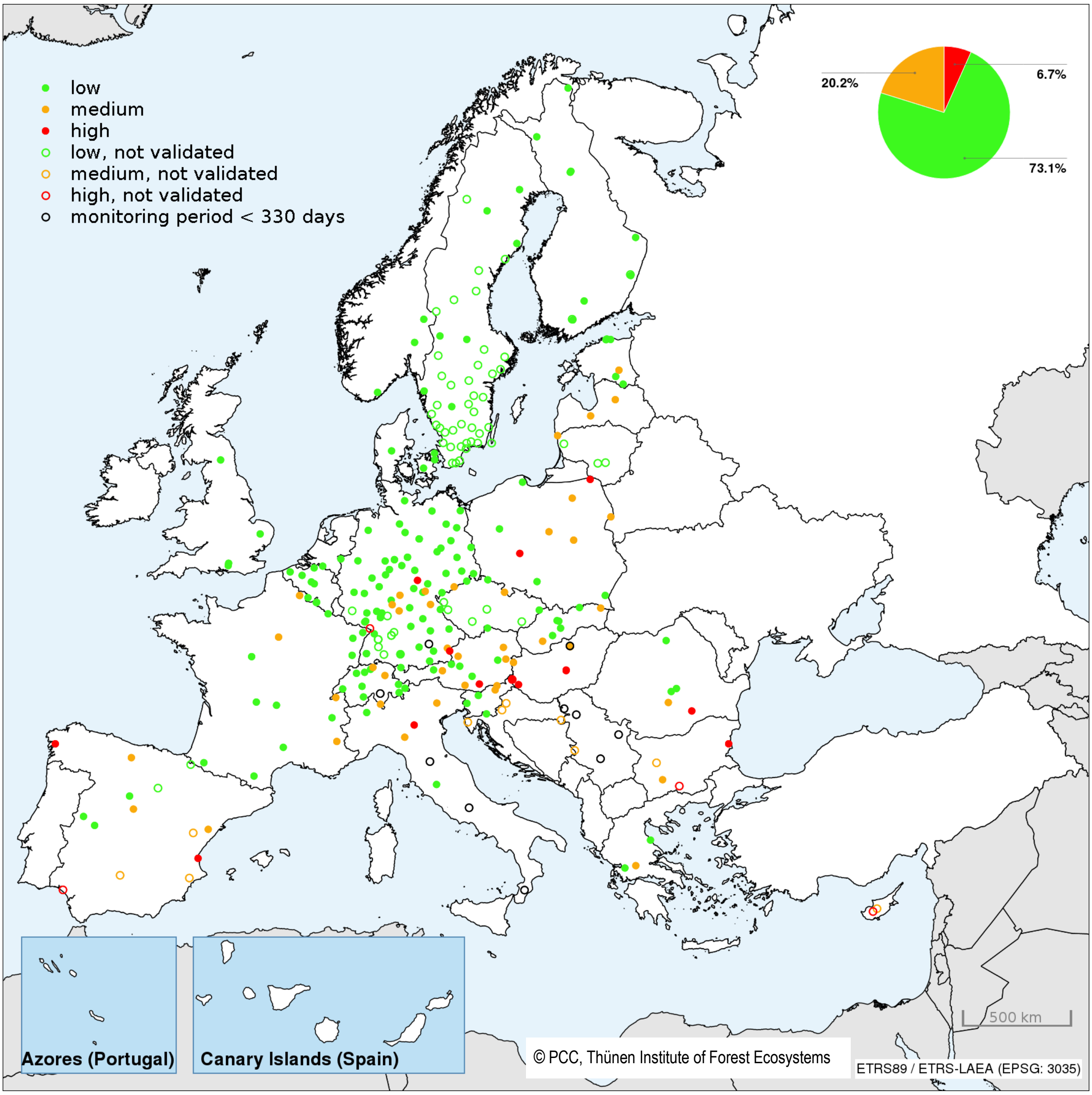

Figure 5-9: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2017 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Points: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (0.0–1.5 kg Mg^{2+} ha^{-1} yr^{-1}), medium (>1.5–3.0 kg Mg^{2+} ha^{-1} yr^{-1}), high (>3.0 kg kg Mg^{2+} ha^{-1} yr^{-1}).

6 ACTIVITIES TO IMPROVE DATA QUALITY IN OZONE SYMPTOM ASSESSMENT WITHIN THE EXPERT PANEL ON AMBIENT AIR QUALITY

Elena Gottardini, Vicent Calatayud, Stefano Corradini, Diana Pitar, Pierre Vollenweider, Marco Ferretti, Marcus Schaub

6.1 Introduction and scientific background

Data quality is a crucial prerequisite for defining the reliability of data and, ultimately, if the data provide useful information on the object of the study. Relatively few studies analyze how the visual assessment of biological indicators are influenced by assessor perception and ability, but all recognize the need for Quality Assurance and Quality Control (QA/QC) procedures (Ferretti and Erhardt 2002; Ferretti and König 2013; Francini et al. 2009; Nali et al. 2006).

One of the main strengths of the ICP Forests programme has been the development of the Quality Assurance (QA) toolkit, a set of instruments and measures that each Expert Panel (EP) and Working Group (WG) can implement within their own QA/QC procedures, with the aim to obtain reliable and comparable data on air pollution effects on European forests (Ferretti et al., 2016).

Within the EP on Ambient Air Quality (AAQ), the QA toolkit consists of:

- ICP Forests Manual, part VIII (Schaub et al. 2016), which describes the procedures for the assessment of ozone visible symptoms, and where a specific chapter is devoted to QA/QC;

- Indicators of data quality, useful to detect and avoid subjectivity in defining the data quality level and documenting its temporal changes;

- Training and intercalibration courses (ICC) for the assessment of ozone visible symptoms on native vegetation at the intensive forest monitoring Level II sites.

The purpose of this contribution is to report (i) on the intercalibration courses since 2000 up to now organized by the EP AAQ, and (ii) on the results obtained with the photo and field exercises carried out during the ICCs. In addition, the following initiatives undertaken to improve data quality for ozone visible symptom validation are also described: (iii) the online tool OSVALD (Ozone Symptom VALidation Database) and (iv) the microscopic analysis of leaves.

6.2 Intercalibration courses on the assessment of ozone visible symptoms

The main purposes of ICCs are (a) to refresh and keep countries and operators updated on the standard methodology for the assessment of ozone visible symptoms described in the ICP Forests Manual, part VIII (Schaub et al., 2016), (b) provide the proper training and knowledge for a correct identification of ozone visible symptoms, thus (c) harmonizing the entire procedure among operators. Altogether, this ensures that data collected during the field campaigns are of high-quality and comparable across Europe.

From 2000 to 2018, fourteen ICCs have been organized across Europe (Table 6-1). Overall, 390 participants from 34 different countries attended these courses (Table 6-2). The number of participating countries at each course is reported in Figure 6-1. Out of the total of ICP Forests member countries that participated in the 14 ICCs, 85% had attended at least one course by 2004.

Table 6-1. List of the UNECE-ICP Forests Intercalibration courses on the assessment of ozone visible symptoms.

No	Date	Place	No of partici-pants	No of coun-tries
1st	17-19.09.2000	Morella, Spain	35	17
2nd	22-24.08.2001	Lattecaldo, Switzerland & Moggio, Italy	48	21
3th	25-27.09.2002	Nice, France	35	15
4th	25-27.08.2003	Lattecaldo, Switzerland & Moggio, Italy	31	15
5th	16-18.08.2004	Lattecaldo, Switzerland	31	15
6th	28-30.09.2005	Follonica, Italy	25	10
7th	28-31.08.2006	Lattecaldo, Switzerland	25	11
8th	27-29.08.2007	Ljubljana, Slovenia	28	11
9th	27-29.08.2008	Trento, Italy	17	8
10th	21-24.09.2009	Budapest, Hungary	27	14
11th	21-24.09.2010	Valencia, Spain	31	11

N.	Date	Place	No of partici-pants	No of coun-tries
12th	12-15.09.2016	Brașov, Romania	21	9
13th	28-31.08.2017	Trento, Italy	14	6
14th	10-13.09.2018	Poreč, Croatia	22	13

Table 6-2. List of countries represented at at least one UNECE-ICP Forests Intercalibration course on the assessment of ozone visible symptoms.

Countries	
Austria	Luxemburg
Belgium	Netherlands
Brazil	Norway
Bulgaria	Poland
Croatia	Portugal
Cyprus	Republic of Moldova
Czech Republic	Romania
Denmark	Russia
Finland	Serbia
France	Slovakia
Germany	Slovenia
Greece	Spain
Hungary	Switzerland
Italy	Turkey
Japan	Ukraine
Latvia	United Kingdom
Lithuania	USA

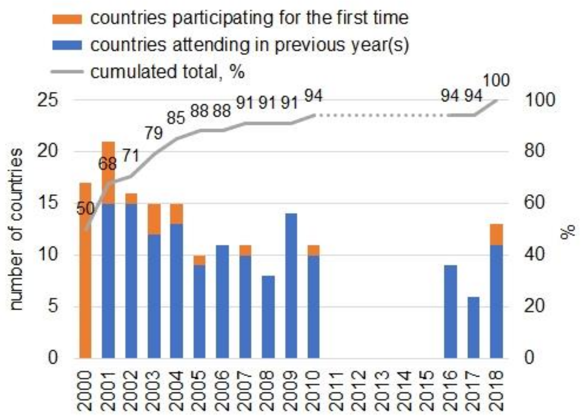

Figure 6-1. Number of countries represented at the UNECE-ICP Forests Intercalibration courses on the assessment of ozone visible symptoms.

During the UNECE-ICP Forests Intercalibration courses on the assessment of ozone visible symptoms, two main types of exercises are proposed to the participants. The first one is an indoor photo exercise, which consists of a slide show showing ozone-like (symptoms that are/are not induced by ozone) symptoms on woody species that are frequently found in European forests; operators have to assess each picture if ozone-induced visible symptoms are present or not. To facilitate the management of this exercise and related outputs, an online version has been recently developed using Google Forms (here not shown, for quality assurance reasons).

The second exercise takes place at a selected forest edge and consists of the assessment of visible symptoms on woody species in a forest edge transect (i.e., the so called Light Exposed Sampling Site, LESS) following the standard methodology described in the ICP Forests Manual, part VIII (Schaub et al., 2016); for this exercise, two outputs are considered for quality assurance purposes: the number of 1x2m quadrates along the LESS with symptomatic plants, and the number of symptomatic species per LESS.

Both, indoor and outdoor exercises are also carried out by the control team, which includes the most experienced experts whose score serves as reference to calculate the agreement with each operator. The agreement results are evaluated in relation to the data quality objectives (DQO) and data quality limits (DQL) described in the ICP Forests Manual, part VIII, chapter 5.2.3 and 5.2.4 respectively, and reported in Tab. 6-3 and 6-4 (amended for LESS survey variable).

Table 6-3. Data quality objectives (DQO) for operators assessing ozone visible symptoms.

Type of exercise	Variable	Data quality objectives
Photo exercise	Scoring visible symptoms of several woody plant species (ozone-induced/not ozone-induced)	⩾ 70% agreement with control
LESS survey	Number of quadrates including symptomatic plants	Control ± 2 quadrates
LESS survey	Number of symptomatic species per LESS	Control ± 2 species

Table 6-4. Data quality limits (DQL) for the assessment of ozone visible symptoms.

Type of exercise	Variable	Data quality objectives
Photo exercise	Scoring visible symptoms of several woody plant species (ozone-induced/not ozone-induced)	⩾ 70% of the individuals fulfill DQO
LESS survey	Number of quadrates including symptomatic plants	⩾ 70% of the individuals fulfill DQO

6.3 Results from photo and field exercises

Data on photo and field (LESS) exercises available for being elaborated were those from the more recent ICCs (2008-2018). Results in terms of frequency of operators that met DQO at each course are shown in Figures 6-2 and 6-3, for the photo and LESS exercise, respectively.

As for the photo exercises (Fig. 6-2), in 2008, 2009 and 2010 results were above the DQL; then, after a 5-years gap in the organization of ICCs, data quality decreased below the DQL. In 2018, data quality was again slightly above the DQL. It should be noticed that in 2016 a new on-line photo exercise was implemented and further adjusted by excluding few ambiguous and unclear pictures. On average, the frequency of operators meeting the data quality during the six courses was 68.7%, slightly below the DQL of 70%.

Figure 6-2. Frequency of operators that met the DQO of ≥70% in scoring symptoms induced or not by ozone, in photo exercises carried out during the more recent UNECE-ICP Forests Intercalibration courses on the assessment of ozone visible symptoms.

The field exercises carried out along the LESS resulted in data quality values above the DQL, except in 2017 when only 25% of teams (1 out of 4) met the DQO. It should be mentioned that in 2017, a high number of symptomatic quadrates (11 out of 18) was found by the reference team (i.e. control), increasing the likelihood of the differences between operators and the reference team to exceed ± 2. Furthermore, for the LESS exercises, on average the frequency of operators or teams meeting the data quality in the six courses considered was 78%, i.e. above the data quality limit of 70%.

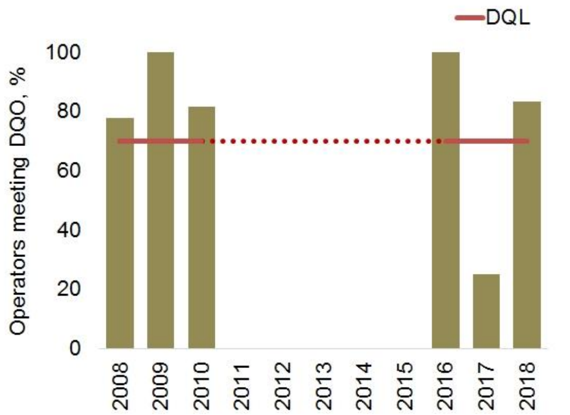

Figure 6-3. Frequency of operators that met the DQO of ≥70% during the assessment of the number of quadrates with plants showing ozone-induced symptoms along the Light Exposes Sampling Site carried out during the more recent UNECE-ICP Forests Intercalibration courses on the assessment of ozone visible symptoms.

6.4 Ozone Symptom VALidation Database – OSVALD

OSVALD is an online tool for ozone symptom validation through the visual assessment of pictures. The surveyor who finds ozone-like symptoms in the field, can take a picture, upload it to OSVALD and provide additional information in a form. After each upload of a picture, a group of experts receives a notification email about a new picture to be assessed and validated. Afterwards, users can access the pictorial database and check the validation results for all pictures available. This way, OSVALD can serve both, as a validation and a training tool.

The OSVALD system allows managing users with different roles: there is the "admin" user who has all permissions, the "validator" user and the "basic" user who can upload their images and view all images already approved by "validator".

The software is completely written by FEM with open source program, and uses web server Apache, the MySQL databases with PHP and Javascript languages. The entire system runs on the Linux Server (Centos 7.1); the images are stored in their original version on the filesystem and the thumbnails are created automatically to allow a faster preview.

The images are visible only after the approval by two validators who can confirm whether there are any ozone symptoms. The software records any users' activity into log files. There is also an automatic backup system.

More detailed information on how to access to OSVALD and use it is available at: http://appmeteo.fmach.it/osvald/index.php

6.5 Microscopic analysis of leaves for ozone symptom validation

For additional validation of ozone-like symptoms on leaves, microscopic analyses are recommended in the ICP Forests Manual, part VIII. Recently, an original field microscopy application, using cell phone and simple processing instruments, has been developed and implemented during each ICC since 2016. The main objectives are (a) providing a sound and easy validation of ozone symptoms in the field, (b) ascertain the diagnosis in the case of dubious cases (for example, leaf reddening), (c) raising the understanding regarding ozone effects in leaves and (d) providing the participants with simple and useful tools for their surveys. Besides a cell phone with camera and lamp functions, the basic instruments include a rather cheap lens and a free app (https://www.nurugo.com/collections/all/products/nurugo-micro), together with a stative (https://www.instructables.com/id/10-Smartphone-to-digital-microscope-conversion/) easy to build and adapt for the purpose. With this equipment, excellent macro-pictures are easily obtained (Fig. 6-4C). In addition, 50 µm thick sections are prepared by means of a custom-made hand microtome and disposable blades. They can be observed either without staining (Fig. 6-4D) or after a simple metachromatic staining (Fig. 6-4E). In this way, various structural bioindications of ozone injury can be analyzed, enabling symptom validation in most cases. Since 2016, 16 samples from 11 species were exemplarily processed in the field during four ICCs, and the results communicated to the participants directly during the exercises and during the ICC closing seminars, and provided in the form of a validation table and a report at the completion of each ICC. Each validation includes the indication of plant response (e.g., for Fig. 6-4: hypersensitive reaction, HR), the classification of injury according to three categories [ozone injury (e.g., Fig. 6-4); likely ozone injury; other], together with a diagnosis (e.g., for Fig. 6-4: discrete groups of cytorrhized and oxidized cells in the upper mesophyll).

6.6 Conclusion

Data quality is a key issue in ICP Forests. It has been considered in ozone symptom assessment since the beginning in the ICP Forests programme, and properly faced through the adoption of specific, dedicated activities. Gaps in this activity may have an impact on data quality and thus on survey results. As such, QA/QC activities are pivotal for the success of the assessment of ozone visible symptoms within the ICP Forests programme and must be implemented alongside the annual surveys. Quality assurance activities undertaken within the EP on AAQ triggered outputs that are valuable to improve the program itself (e.g. Bussotti et al. 2003, 2006) and the results obtained in different member and non-member countries through the application of the ICP Forests method (e.g., Araminiene et al. 2019; Dalstein and Ciriani 2019; Feng et al. 2014; Gottardini et al. 2018; Novotny et al. 2010). Providing data with a certain quality, the survey on ozone visible symptoms carried out by the EP on AAQ - the largest European program in assessing ozone levels and effects on vegetation - will permit to obtain a large-scale, long-term picture of the risk that ozone poses on European forests.

6.7 References

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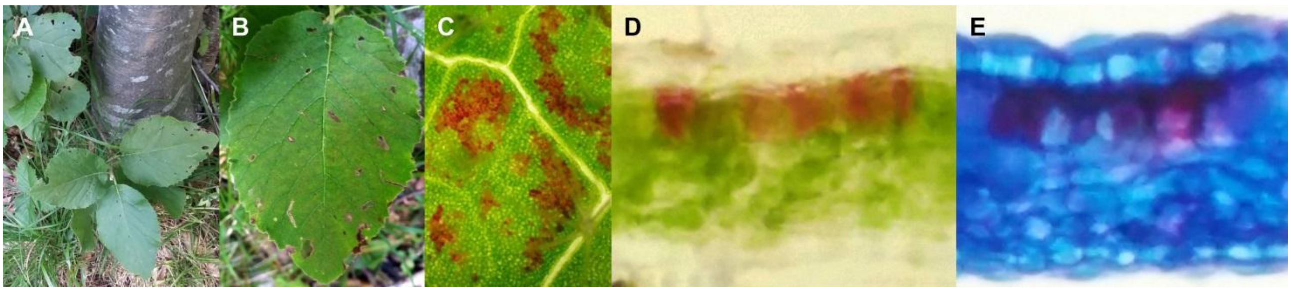

Figure 6-4. Exemplary microscopical validation of ozone injury in *Viburnum lantana,* realized in the field using cell phone and simple microscopy equipment (13th ICC, Trento, Italy, 29.08.2017). A, B: symptomatic plant and leaf material; C: macro-picture of symptoms; D, E: micrographs of fresh hand-microtomed sections, 50 µm thick, without (D) and with (E) staining [triple coloration (astra blue 0.025%, safranin and basic fuchsin 0.005% each, in acetic acid 2%); magnification: *circa* 350x].

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7 TREE CROWN CONDITION IN 2018

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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[1].

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 assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2018, as well as long-term trends for the main species and species groups.

7.2 Methods of the 2018 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).

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

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 7-4, class 2 is subdivided into class 2-1 (> 25–40%) and class 2-2 (> 40–60% defoliation).

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

Table 7-2 shows countries and the number of plots assessed for crown condition parameters from 2009 to 2018, and the total number of sample trees submitted in 2018. The number of trees used for analyses differs from the number of submitted trees due to the application of various data selection procedures. 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.

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, buds and fruits; and (c) stem and collar. A further specification of the affected part along with a symptom description is given.
- **Determination of the damage cause (causal agents / factors)**
  The 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.

Table 7-2: Number of plots assessed for crown condition parameters from 2009 to 2018 in countries with at least one Level I crown condition survey since 2009, and total number of sample trees submitted in 2018

Country	Plots 2009	2010	2011	2012	2013	2014	2015	2016	2017	Plots 2018	Trees 2018
Andorra	3	3	3	3	11	11	12				
Austria		135									
Belarus	409	410	416		373		377				
Belgium	26	9	9	8	8	8	8	53	53	52	554
Bulgaria	159	159	159	159	159	159	159	159	160	160	5596
Croatia	83	83	92	100	105	103	95	99	99	99	2376
Cyprus	15	15	15	15	15	15	15			15	367
Czechia	133	132	136	135		138	136	136	135	132	4995
Denmark	16	17	18	18	18	18	18	17	17	17	407
Estonia	92	97	98	97	96	96	97	98	98	98	2404
Finland	886	932	717	785							
France	500	532	544	553	550	545	542	533	527	521	10604
Germany	412	411	404	415	417	422	424	421	416	410	9825
Greece	97	98				57	47	23	36	40	936
Hungary	73	71	72	74	68	68	67	67	66	68	1503
Ireland	32	29		20							
Italy	252	253	253	245	247	244	234	246	247	249	5640
Latvia	207	207	203	203	115	116	116	115	115	115	1735
Lithuania	72	75	77	77	79	81	81	82	82	81	1953
Luxembourg					4	4	4	4	3	3	72
Montenegro		49	49	49	49			49	49	49	1176
Netherlands	11	11									
Norway	487	491	496	496	618	687	554	629	630	623	6072
Poland	376	374	367	369	364	365	361	353	352	348	6930
Rep. of Moldova									9	9	216
Romania	227	239	242	241	236	241	242	243	246	246	6008
Russian Fed.	365	288	295								
Serbia	122	121	119	121	121	128	127	127	126	126	2967
Slovakia	108	108	109	108	108	107	106	103	103	101	4508
Slovenia	44	44	44	44	44	44	44	44	44	44	1078
Spain	620	620	620	620	620	620		620	620	620	14880
Sweden	857	830	640	609	740	842	839	701	618	760	2477
Switzerland	48	48	47	47	47	47	47	47	47	47	1028
Turkey	560	554	563	578	583	531	591	586	598	601	13970
United Kingdom		76									
TOTAL	7292	7521	6807	6189	5795	5697	5343	5555	5496	**5634**	**110277**

– **Quantification of symptoms (damage extent)**

The extent is the estimated damage to a tree, specifying the percentage of affected leaves/needles, branches or stem circumference due to the action of the causal agent or factor.

Additional parameters

Several other tree, stand and site parameters are assessed, providing additional information for analysis of the crown condition data. For the full information, please refer to Eichhorn et al. (2016). Analysis of these parameters is not within the scope of this report.

Tree species

For the analyses in this report, the results for the four most abundant species are shown separately in figures and tables. *Fagus sylvatica* is analysed together with *F. sylvatica* ssp. *moesiaca*. Some species belonging to the *Pinus* and *Quercus* genus were combined into species groups as follows:

- 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*).

Of all trees assessed for defoliation on the Level I network on 2018, *Pinus sylvestris* was the most abundant tree species (16.8% of all trees), followed by *Picea abies* (12.5%), *Fagus sylvatica* (10.5%), *Pinus nigra* (4.9%), *Quercus petraea* (4.3%), *Q. robur* (4.1%), *Q. ilex* (3.6%), *Pinus brutia* (3.2%), *Q. cerris* (3.1%), *Betula pubescens* (2.4%), *Pinus halepensis* (2.4%), *Quercus pubescens* (2.1%), *Abies alba* (2.0%), *Betula pendula* (2.0%) and *Pinus pinaster* (1.8%). Most Level I plots with crown condition assessments contained one (49.5%) or two to three (37.9%) tree species per plot. On 10.4% of plots four to five tree species were assessed, and only 2.2% of the plots featured more than five tree species. In 2018, 49.8% of the assessed trees were broadleaves and 50.2% conifers. The species percentages differ slightly for damage assessments, as selection of trees for assessments in participating countries varies.

Statistical analyses

For calculations, selection procedures were applied in order to include only correctly coded trees in the sample (Tables 7-4 and 7-5). 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 7-3 and in the online supplementary material[1].

Trends in defoliation were calculated according to Sen (1968) and their significance tested by the non-parametric Mann-Kendall test (tau). These methods are appropriate 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 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 period 1999–2018. For the Mann-Kendall test, a significance level of $p \leq 0.05$ was 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. Maps of defoliation trends for the period 2011–2018 can be found in the online supplementary material[1]. For all trend calculations plots were included if assessments were available for at least 80% of the period of interest. All queries and statistical analyses were conducted in R/RStudio software environment (R Core Team 2016).

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, various densities of national grids (1x1 km to 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.

[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 2018

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 2018							
Andorra	47	18	18	15	2	4x4	12	289
Austria	No data available for 2018							
Belarus	No data available for 2018							
Belgium-Flanders	1351	146	146			4x4	69	1481
Belgium-Wallonia	1684	555		205	270	varying	44	366
Bulgaria	11100	4244	4244	1255	2989	4x4/16x16	160	5596
Croatia	5654					16x16	99	2376
Cyprus	925	298	138	172	0	16x16	15	367
Czechia	7887	2666	2666	1956	710	16x16	132	4914
Denmark	4308	625		301	292	varying	362	2051
Estonia	4534	2331	2331	1170	1161	16x16	98	2404
Finland	No data available for 2018							
France	54883	15840	13100	4041	9884		528	10744
Germany	35721					16x16	410	9867
Greece	13205	6513	6513	1430	5083	16x16	40	935
Hungary	9300	1940	1940	199	1741	16x16	78	1869
Ireland	No data available for 2018							
Italy	30128	10345	6323	1664	4659	16x16	249	4482
Latvia	6459	3223	3223	1403	1820	16x16	115	1726
Lithuania	6529	2196	2056			4x4/16x16	1068	6605
Luxembourg	258	91	81	27	59	4x4	52	1200
North Macedonia	No data available for 2018							
Rep. of Moldova	3384	401	375	8	367	2x2	618	14055
Montenegro	1381	827	827	207	620	16x16	49	1176
Netherlands	No data available for 2018							
Norway	32376	12100	12100	7184	4916	3x3	1834	11071
Poland	31268	9230	9230	6321	2909	8x8	2023	40460
Portugal	No data available for 2018							
Romania	23839	6233	6233	1873	4360	16x16	245	5900
Russian Fed.	No data available for 2018							
Serbia	8836	2360	1868	179	2181	4x4/16x16	130	2968
Slovakia	4904	2014	2014	768	1246	16x16	100	3701
Slovenia	2028					16x16	44	1056
Spain	49880	18289	15872	6767	10059	16x16	620	14880
Sweden	47496	22846	22846	18709	1686	varying	3326	7306
Switzerland	4129	1279		778	501		47	1039
Turkey	77846	21537	9057	13158	8379	16x16	601	13957
Ukraine	No data available for 2018							
United Kingdom	No data available for 2018							
TOTAL							12 391	159 615

7.3 Results of the transnational crown condition survey

Defoliation

The transnational crown condition survey in 2018 was conducted on 110 277 trees on 5 634 plots in 27 countries (Table 7-2). Out of those, 103 797 trees were assessed in the field for defoliation (Table 7-4).

The overall mean defoliation for all species was 22.6% in 2018; there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2017 (Table 7-4). Broadleaved trees showed a higher mean defoliation than coniferous trees (22.9% vs. 21.3%). Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' and 'slight' (75.2% combined) than broadleaves (70.6%) and a lower frequency of dead trees (0.6 vs. 0.7%).

Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (26.1% and 25.8%, respectively). Common beech had the lowest mean defoliation (20.8%) followed by Norway spruce with 21.0%, deciduous (sub-) Mediterranean oaks (21.2%) and Mediterranean lowland pines (21.3%). Mediterranean lowland pines also had the highest percentage (79.4%) of trees with ≤ 25% defoliation, while deciduous temperate oaks had the lowest (61.0%). The strongest increase in defoliation from 2017 to 2018 occurred in deciduous temperate oaks (2.2%) while evergreen oaks had the largest decrease in defoliation (-1.8%) but overall, the differences in defoliation between 2017 and 2018 were not very large.

Mean defoliation of all species at plot level in 2018 is shown in Figure 7-1. Almost three quarters (71.9%) of all plots had a mean defoliation up to 25%, and only 0.8 % of the plots showed severe defoliation (more than 60%). Plots with mean defoliation over 40% were primarily located from eastern Spain, through southeast (Mediterranean) France to north-west Italy, then from Czechia through Slovakia into Hungary, and in western Bulgaria. Plots with low mean defoliation were found across Europe, but mainly in south-eastern Norway, Estonia, Latvia, northern Germany, Romania, central Serbia and Turkey.

The following sections describe the species-specific mean plot defoliation in 2018 and the over-all trend and yearly mean plot defoliation from 1999 to 2018. For maps on defoliation of individual tree species in 2018, please refer to the online supplementary material[1].

Table 7-4: Percentage of trees assessed in 2018 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2017 in parentheses) and the number of trees in each group. Dead trees were not included when calculating mean defoliation.

Main species or species groups	Class 0 0-10	Class 1 >10-25	Class 2-1 >25-40	Class 2-2 >40-60	Class 3 >60	Class 4 dead	Mean defoliation	No. of trees
Common beech (*Fagus sylvatica*)	33.6	40.0	18.3	5.7	2.2	0.2	20.8 (+0.6)	12 417
Deciduous temperate oaks	20.1	40.9	26.2	9.2	3.3	0.4	25.8 (+2.2)	9 117
Dec. (sub-) Mediterranean oaks	30.6	44.2	16.4	5.9	2.5	0.4	21.2 (+0.2)	8 043
Evergreen oaks	9.0	57.5	22.3	7.2	3.3	0.7	26.1 (-1.8)	4 610
Other broadleaves	30.0	42.9	14.9	6.2	4.7	1.3	22.7 (+0.9)	17 508
Scots pine (*Pinus sylvestris*)	24.6	51.2	14.8	5.7	2.9	0.7	22.0 (+1.3)	17 919
Norway spruce (*Picea abies*)	33.1	37.7	20.2	5.9	2.2	0.8	21.0 (+1.2)	12 952
Austrian pine (*Pinus nigra*)	33.5	40.8	14.2	6.2	5.0	0.2	22.2 (+1.9)	5 332
Mediterranean lowland pines	18.5	60.9	14.0	4.1	1.8	0.7	21.3 (-0.8)	8 459
Other conifers	38.4	38.6	14.9	5.5	2.2	0.4	19.5 (+1.1)	7 440
TOTAL								
Broadleaves	27.3	43.3	18.6	6.7	3.4	0.7	22.9 (+0.7)	51 695
Conifers	28.6	46.6	16.0	5.5	2.7	0.6	21.3 (+1.0)	52 102
All species	28.0	45.0	17.3	6.1	3.0	0.6	22.6 (+0.9)	103 797

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

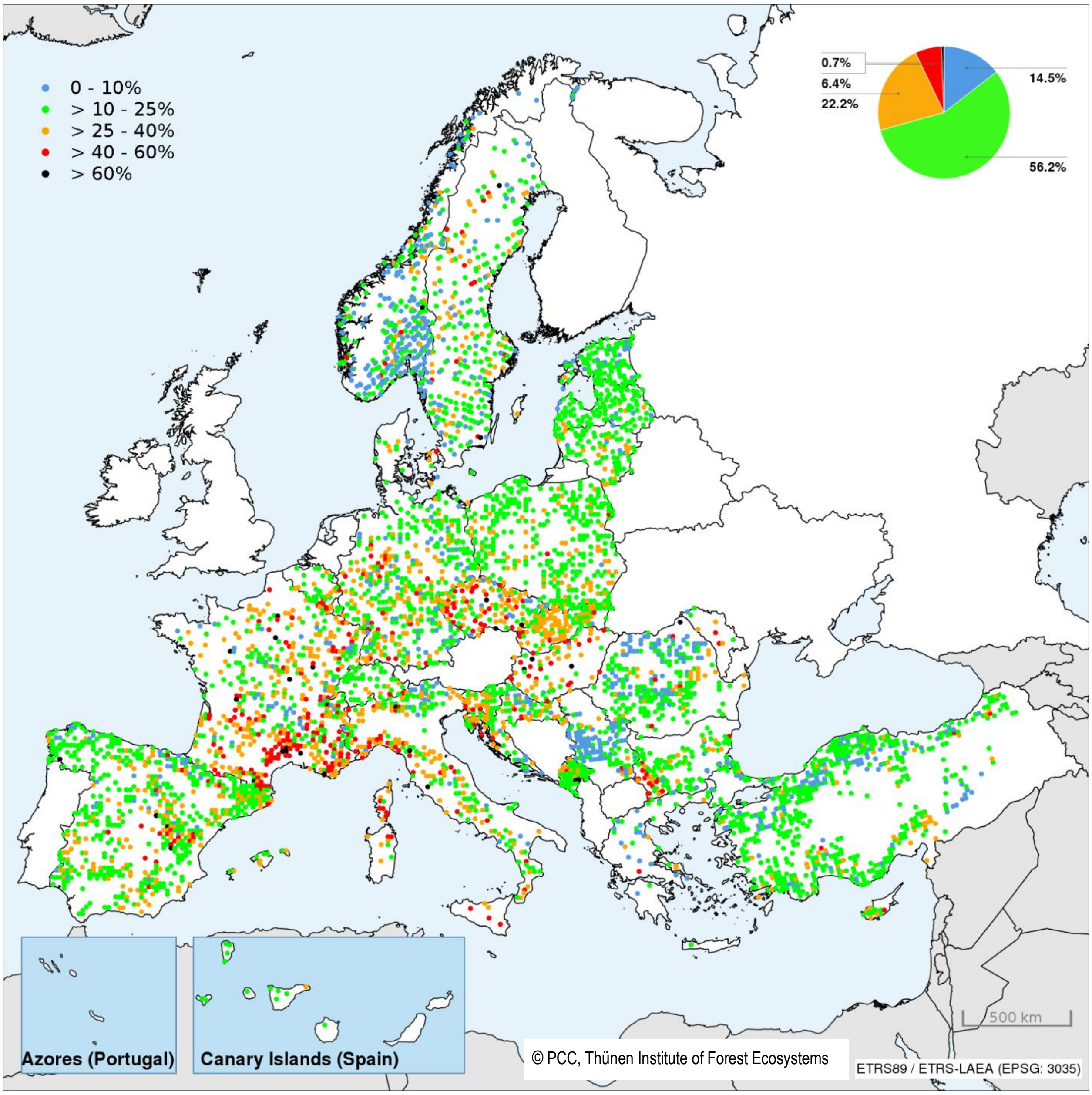
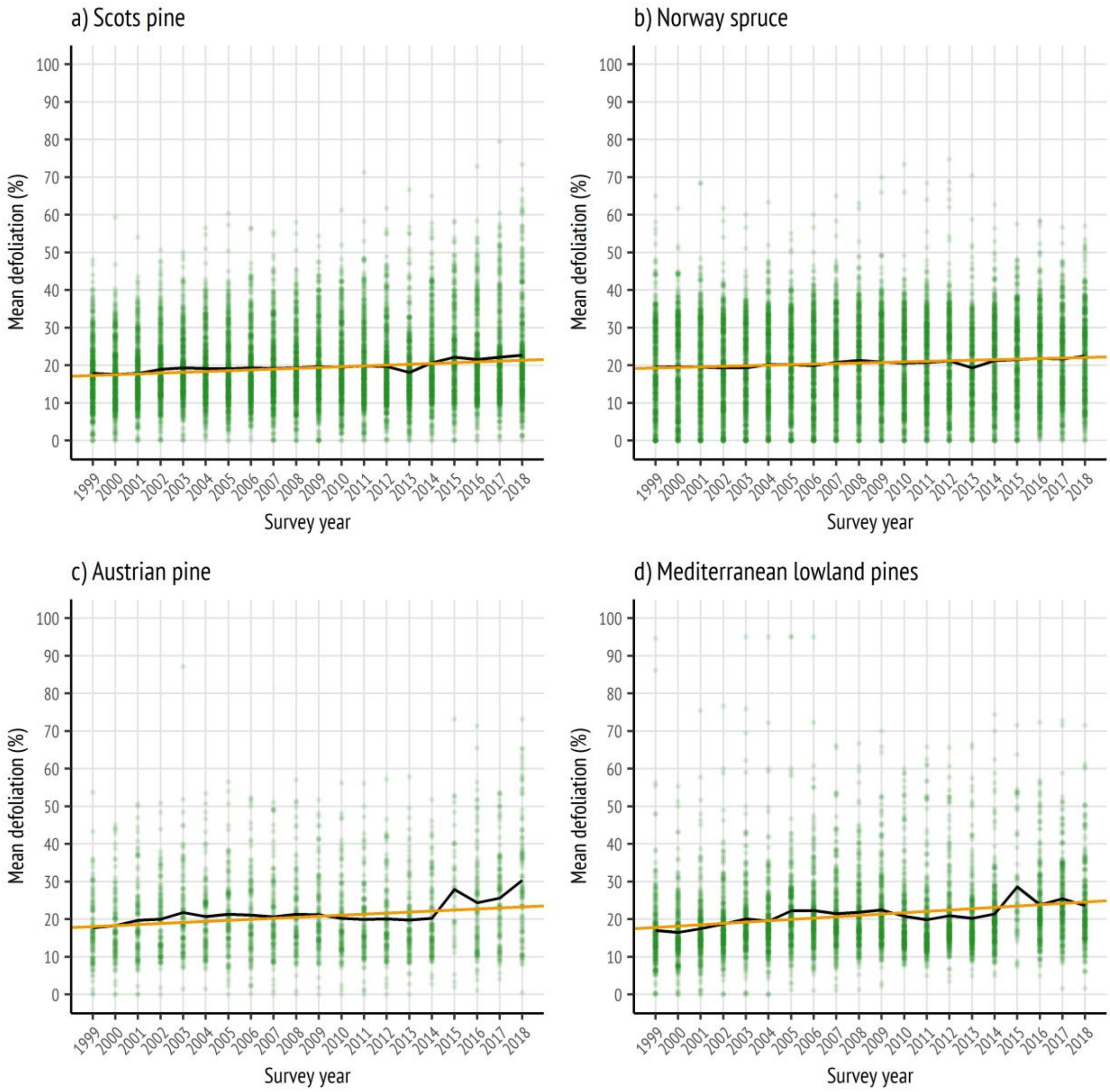
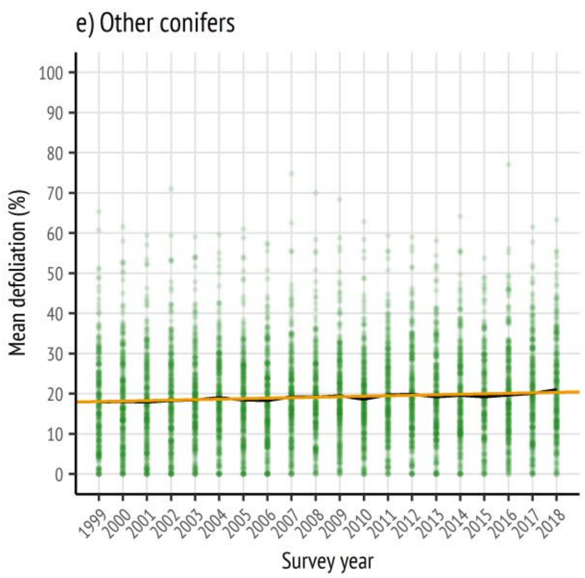
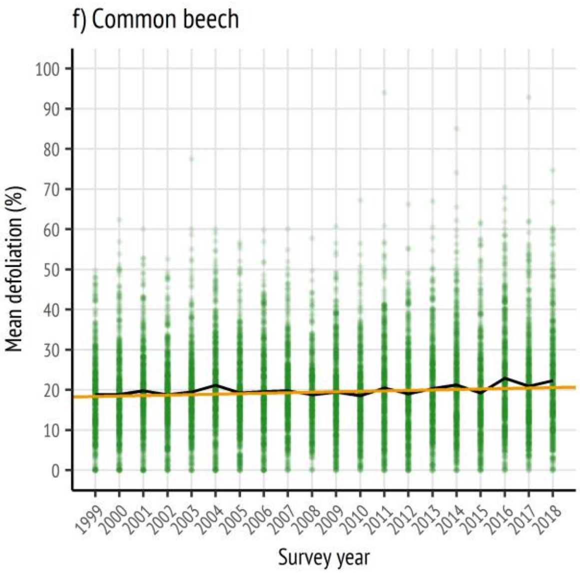


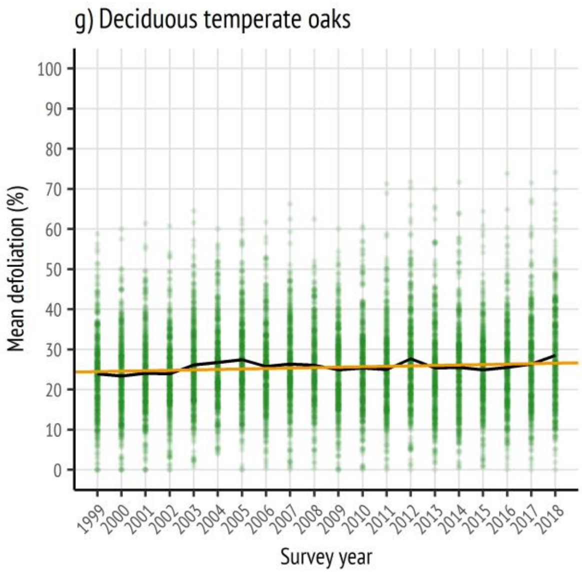
Figure 7-1: Mean plot defoliation of all species in 2018

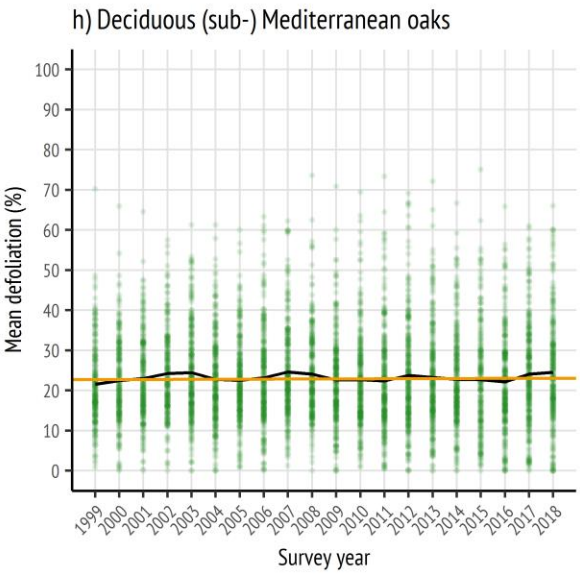


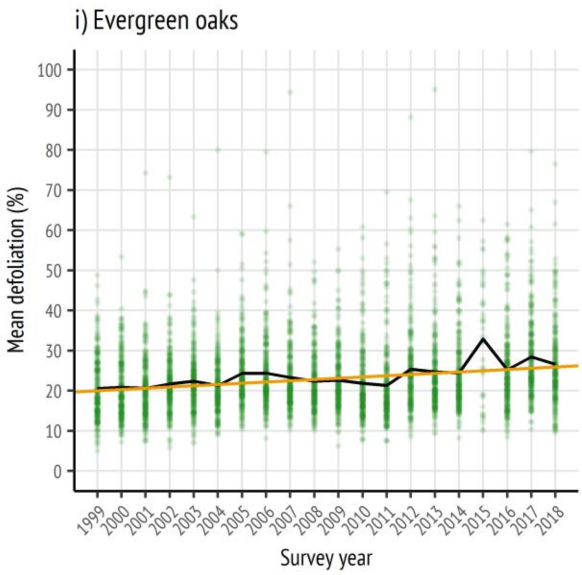


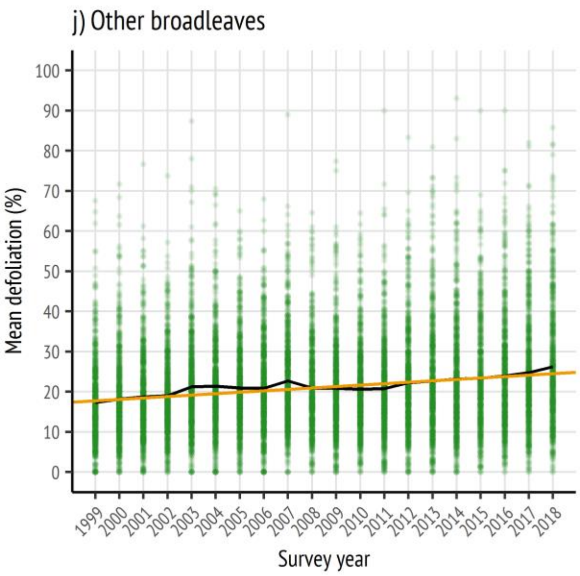
Figures 7-2 a-e: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 1999–2018; points represent annual plot mean values: (a) Scots pine (regional Sen's slope = 0.2130, p < 0.001) (b) Norway spruce (regional Sen's slope = 0.1435, p < 0.001) (c) Austrian pine (regional Sen's slope = 0.2763, p = 0.0179) (d) Mediterranean lowland pines (regional Sen's slope = 0.3569, p < 0.001) (e) other conifers (regional Sen's slope = 0.1233, p < 0.001)











Figures 7-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 1999–2018; points represent annual plot mean values: (f) Common beech (regional Sen's slope = 0.1188, $p < 0.0150$) (g) Deciduous temperate oaks (regional Sen's slope = 0.1074, $p = 0.0980$) (h) Deciduous (sub-) Mediterranean oaks (regional Sen's slope = 0.0208, $p = 0.5376$) (i) Evergreen oaks (regional Sen's slope = 0.3142, $p < 0.001$) (j) other broadleaves (regional Sen's slope = 0.3539, $p < 0.001$)

Scots pine

Scots pine (*Pinus sylvestris*) was the most frequent tree species in the Level I network in 2018 with 18154 assessed trees. 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).

On most of the plots with Scots pine (80.2%), pine trees showed no or only slight mean defoliation (≤ 25% defoliation; please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 19% of the plots was moderate (>25-60% defoliation) and on 0.8% of the plots severe. Plots with the lowest mean defoliation were primarily found in southern Norway, eastern Germany, Estonia and northern Turkey, whereas plots with comparably high defoliation were located in Czechia, western Slovakia, south-eastern France, and western Bulgaria.

There has been a significant over-all trend in mean plot defoliation for Scots pine for the past 20 years, increasing by 2.13% on average every ten years (Figure 7-2a). The mean defoliation across plots showed some fluctuation at the beginning and towards the end of the chosen reporting period, with mean defoliation values steadily above the trend line since 2014.

Norway spruce

Norway spruce (*Picea abies*) is the second most frequently assessed species on the Level I plots with 13480 trees assessed in 2018. 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. Norway spruce is very common in forest plantations effectively enlarging its natural distribution range.

In 2018, Norway spruce trees on 69.2% of the spruce plots had mean defoliation between 0 and 25% (please refer to the online supplementary material[1], Figure S1-2). One quarter (24.7%) of all Norway spruce plots had defoliation up to 10%, on 30.4% of the plots defoliation was moderate (>25-60% defoliation) and severe defoliation was recorded on only 0.5% of the plots. Plots with low mean defoliation were found mostly in southern Norway and Sweden, northern Italy, Romania, Latvia and Estonia. Plots with high mean defoliation values were scattered across Europe.

The over-all 20-year trend in mean plot defoliation of Norway spruce has been slightly increasing (on average 1.4% every ten years) and significant (Figure 7-2b). The annual mean values did not deviate much from the trend line except in 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.

Austrian pine had a mean defoliation of up to 25% on 71.7% of the plots containing this species (please refer to the online supplementary material[1], Figure S1-3). Defoliation was moderate on 25.9% of the plots (>25-60% defoliation) and severe on 2.4% of the plots. Plots with less than 10% mean defoliation were mostly located in Turkey. Plots with higher defoliation were mostly located in parts of France, Spain, Croatia, Hungary, and Bulgaria.

The over-all 20-year trend in defoliation of Austrian pine has been increasing on average by 2.76 % every 10 years (Figure 7-2c). From 2010 to 2014 the annual mean plot defoliation was lower than the trend, but it has been on the rise since then, reaching its absolute maximum in 2018.

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, but they are also important species in other Mediterranean countries. Aleppo and maritime pine are more abundant in the western parts, and Turkish pine in the eastern parts of this area.

In 2018, 76.4% of Mediterranean lowland pine plots had mean defoliation of up to 25% for trees in this group (please refer to the online supplementary material[1], Figure S1-4), but only 4.2% of plots had defoliation up to 10%. Defoliation was moderate on 22.7% of the plots, and severe on 0.9%. Most of plots with defoliation up to 25% were located in Turkey and Spain. Plots with moderate to severe mean defoliation values (>40% defoliation) were mostly located in the proximity to the coastline of the western Mediterranean Sea.

For Mediterranean lowland pines there has been an average increase in the trend of mean plot defoliation of almost 4 percentage points every 10 years (highest increase of all assessed species or species groups), and this trend is highly significant (Figure 7-2d).

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

Common beech

Common beech (*Fagus sylvatica*) is the most frequently assessed deciduous tree species within the ICP Forests monitoring programme (11323 trees assessed in 2018). 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 2018, common beech had up to 10% mean defoliation on 19.8% of the beech plots, a worsening from the year before. Most of these plots were located in Romania and Serbia (please refer to the online supplementary material[1], Figure S1-5). On almost half of the monitored plots (46.8%), beech trees were slightly defoliated (>10–25% defoliation). There were 32.6% of plots with moderate mean defoliation (26–60%), and only 0.8% with severe defoliation (>60%). Plots with low defoliation were found mostly in southeastern Europe, while plots with severe defoliation were predominantly located in France and Germany.

The over-all 20-year trend in mean plot defoliation of common beech has been slightly but significantly increasing by 1.2 percentage points every 10 years (Figure 7-2e). Annual mean values generally stay close to the trendline, but there were two larger deviations from this trend, in 2004 and 2016. In 2004, the annual over-all mean defoliation was higher than the trend as a result of the drought in the preceding year which affected large parts of Europe (Ciais et al. 2005, Seidling 2007, Seletković et al. 2009).

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 2018, mean defoliation of temperate oaks was up to 25% on more than half of the plots (53.1%), while moderate mean defoliation (>25–60% defoliation) was recorded on 45.9% of plots and severe defoliation (more than 60% defoliation) on 1.1% of the plots (please refer to the online supplementary material[1], Figure S1-6). Plots with severe defoliation were located mostly in France, Germany and Croatia. Plots with low and moderate mean defoliation were scattered throughout Europe, while plots with mean defoliation up to 10% were mainly found in Romania, Croatia and Serbia.

There has been no significant over-all trend in mean plot defoliation for deciduous temperate oaks in the past 20 years. 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 increase of oak defoliation in the drought year 2003, followed by a delayed recovery (Figure 7-2f).

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 2018, Mediterranean oaks on 14.1% of the plots had mean defoliation up to 10%, and on 52.8% of the plots between 10 and 25%, yielding a total of 66.9% of plots with mean defoliation up to 25% for these oaks, almost the same as in the previous year. A third (32.9%) of plots showed moderate mean defoliation for Mediterranean oaks, and only 0.2% severe (please refer to the online supplementary material[1], Figure S1-7). Plots with lower mean defoliation were located predominantly in Serbia, Greece and Turkey, while plots with higher mean defoliation were found mostly in Hungary and southeastern France.

There has been no significant over-all trend in mean plot defoliation for deciduous (sub-) Mediterranean oaks for the past 20 years (Figure 7-2g). Mean plot defoliation values generally stay close to the trendline.

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.

On 56.6% of the plots mean defoliation of evergreen oaks was up to 25% (please refer to the online supplementary material[1], Figure S1-8). Moderate defoliation was recorded on 41.8% of plots, and severe on 1.6%. The majority of plots with defoliation of evergreen oaks over 40% were located in southern France including Corsica, and a few in Spain.

Evergreen oaks show a highly significant increase in the over-all trend of mean plot defoliation of 3.1 percentage points every ten years (Figure 7-2h). The defoliation development pattern for evergreen oaks is characterized by several larger deviations from the trendline (however the mean plot value in 2015 results from the lack of assessments on Spanish plots).

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

Damage causes

In 2018, damage cause assessments were carried out on 103 714 trees in 5 505 plots and 26 countries. On 47 327 trees (45.6%) at least one symptom of damage was found, and 711 trees (0.7%) were dead. In total, 67 666 observations of damage were recorded with potentially multiple damage symptoms per tree. On 1 221 plots no damage was found on any tree. The percentage of dead trees is somewhat larger than in the defoliation survey due to the differences in datasets (i.e. not all trees are assessed for both defoliation and damage symptoms).

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 higher for the broadleaved tree species and species groups than for the conifers (Table 7-5). It was highest for evergreen oaks with 1.10 and lowest for Norway spruce with 0.36 symptoms per tree.

Table 7-5: Number of recorded damage symptoms, number of assessed trees and their ratio for the main tree species and species groups in 2018. Multiple damage symptoms per tree and dead trees are included.

Main species or species groups	N damage symptoms	N trees	Ratio
Common beech (*Fagus sylvatica*)	8 272	11 047	0.75
Deciduous temperate oaks	8 134	8 637	0.94
Dec. (sub-) Mediterranean oaks	7 038	8 044	0.87
Evergreen oaks	5 091	4 610	1.10
Other broadleaves	14 071	19 968	0.70
Scots pine (*Pinus sylvestris*)	9 414	17 735	0.53
Norway spruce (*Picea abies*)	4 520	12 541	0.36
Austrian pine (*Pinus nigra*)	3 136	5 341	0.59
Mediterranean lowland pines	4 498	8 468	0.53
Other conifers	3 492	7 323	0.48
TOTAL			
Broadleaves	42 606	52 306	0.81
Conifers	25 060	51 408	0.49
ALL SPECIES	67 666	103 714	0.65

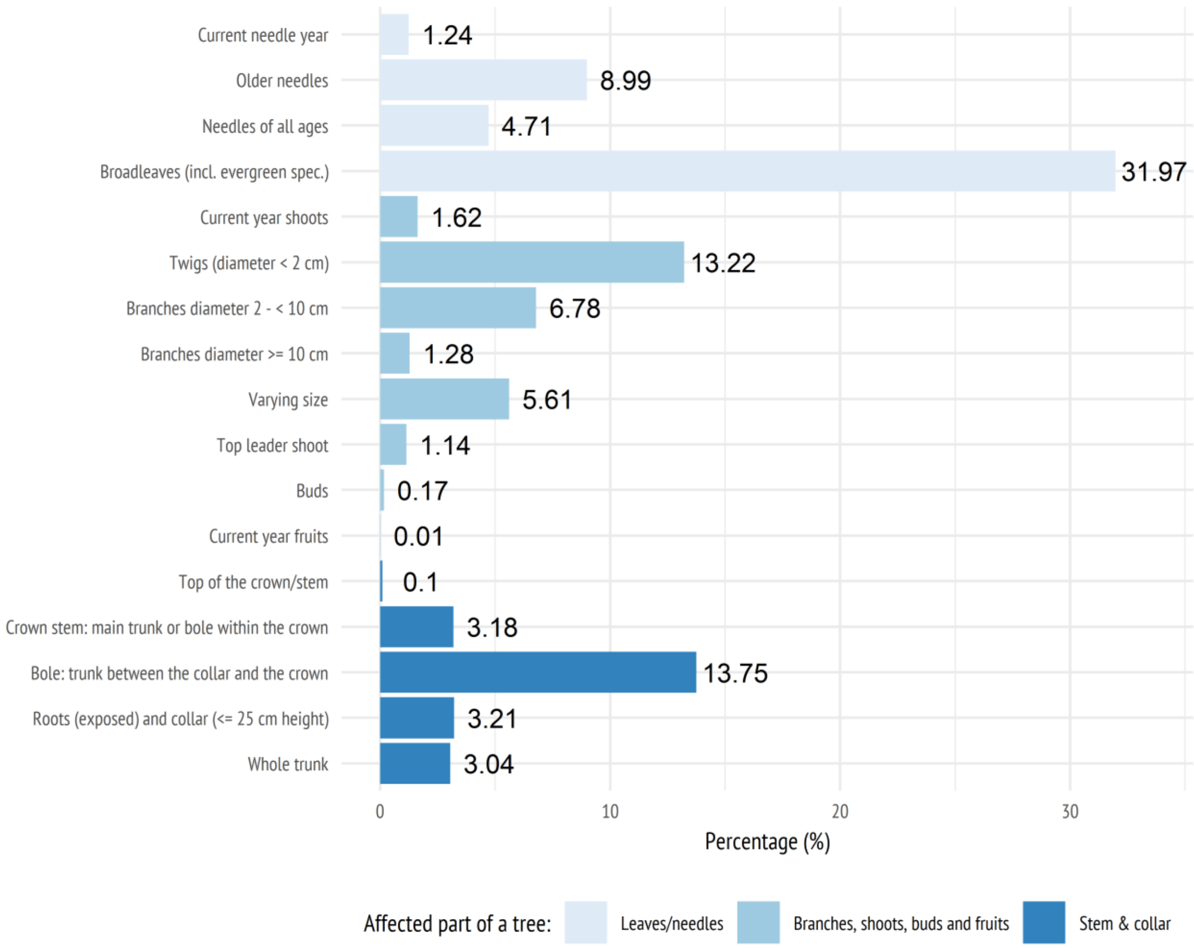

Figure 7-3: Percentage of recorded damage symptoms, affecting different parts of a tree. Multiple affected parts per tree were possible. Dead trees are not included (n=66 955)

Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (32.0%), followed by twigs and branches (26.9%), and stems (20.0%; Figure 7-3). Needles were also often affected (14.9%), while roots, collar, shoots, buds and fruits were less frequently affected.

More than half (52.8%) of all recorded damage symptoms had an extent of up to 10%, 38.6% had an extent between 10% and 40%, and 8.6% 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 27.3% of all recorded damage symptoms (Figure 7-4). Almost half of the symptoms caused by insects were attributed to defoliators (47.3%), the most frequent of all specified damage causes. Wood borers were responsible for 15.6%, leaf miners for 14.1%, and gallmakers for 7.7% of the damage caused by insects.

Abiotic agents were the second major causal agent group responsible for 16.4% of all damage symptoms. Within this agent group, half of the symptoms (49.7%) were attributed to drought, while snow and ice caused 9.6%, wind 8.0%, and frost 3.7% of the symptoms.

The third major identified cause of tree damage were fungi with 11.3% of all damage symptoms. Of those, 21.9% showed signs of decay and root rot fungi, followed by canker (17.6%), needle cast and needle rust fungi (14.4%), blight (10.4%) and powdery mildew (9.4%).

Direct action of man, which includes silvicultural operations and mechanical damage from vehicles, accounted for 4.4% of all recorded damage symptoms. The damaging agent group 'Game and grazing' was of minor importance (1.3%). Fire caused 0.6% of all damage symptoms. The agent group 'Atmospheric pollutants' refers here only to local incidents mainly in connection with factories, power plants, etc. Visible symptoms of direct atmospheric pollution impact, however, were very rare (0.03% of all damage symptoms). Other causal agents were responsible for 9.7% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable amount of symptoms (28.9%) could not be identified in the field.

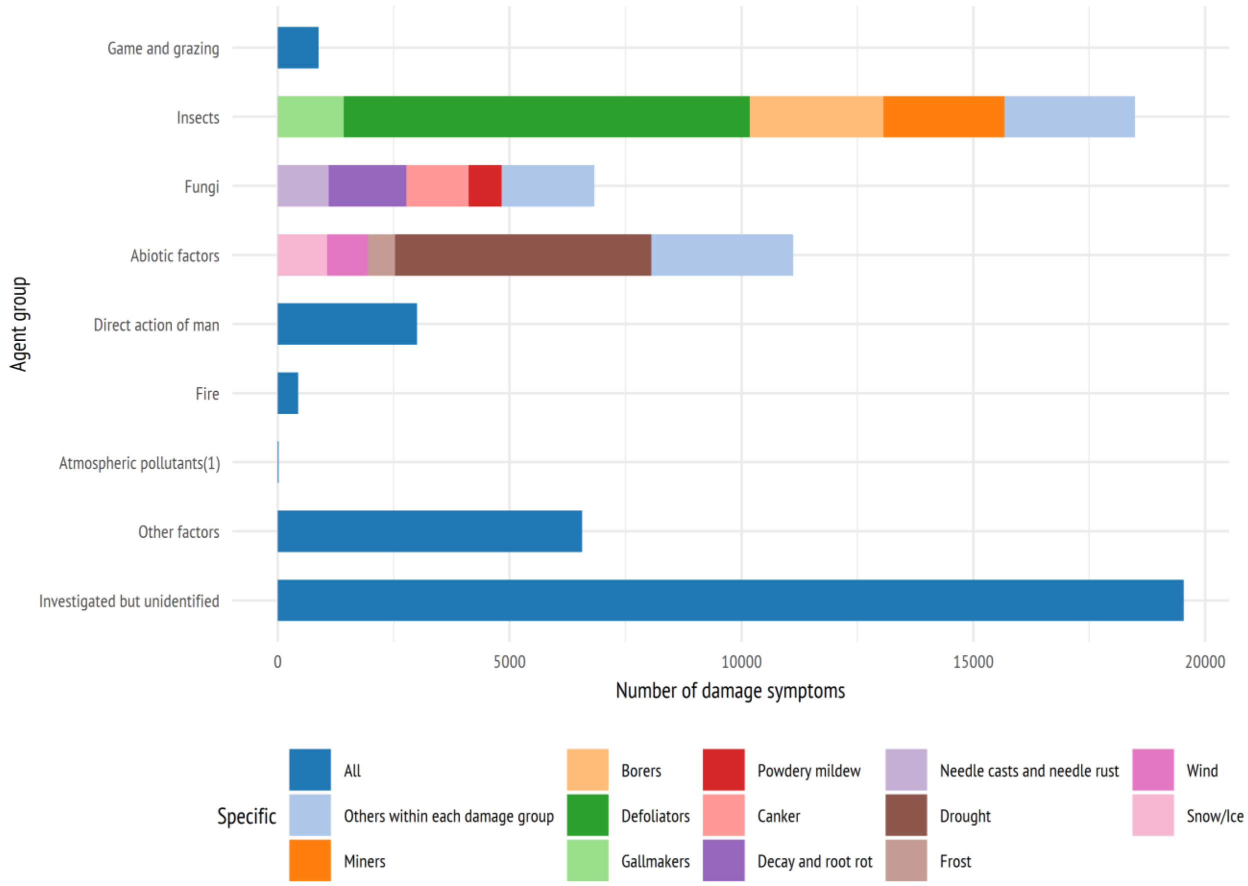

Figure 7-4: Number of damage symptoms according to agent groups and specific agents/factors. Multiple damage symptoms per tree were possible, and dead trees are included (n=67 666). (1) Visible symptoms of direct atmospheric pollution impact only

The occurrence of damaging agent groups differed between major species or species groups (Figure 7-5). Insects were the most important damaging agent group for deciduous temperate oaks (causing 41.2% of all damage), common beech (39.2%), deciduous (sub-) Mediterranean oaks (35.3%), and Austrian pine (29.5%), while insect damage was not so common in Scots pine (10.0%) and Norway spruce (6.3%). Abiotic factors caused by far the most damage in evergreen oaks (44.8%) and Mediterranean lowland pines (38.2%). Fungi were important damaging agents for Austrian pine (17.1%), Scots pine (15.6%), evergreen oaks (13.8%) and deciduous temperate oaks (13.2%). Direct action of man was of little importance in general; it had the highest impact on Norway spruce (14.4%) and Scots pine (8.2%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (11.2%). Fire affected mostly Mediterranean conifer species – 1.1% of both Austrian pine and Mediterranean lowland pine trees were affected. The percentage of recorded but unidentified damage symptoms was quite low in evergreen oaks (8.7%) but large for Norway spruce (43.4%), deciduous (sub-) Mediterranean oaks (34.3%), common beech (31.5%), and Scots pine (31.4%).

The most important specific damaging agents for common beech were mining insects (causing 23.6% of the damage symptoms), followed by defoliators (9.6%) and drought (2.7%). Defoliators were also frequently causing damage on deciduous temperate oaks (20.1%), while powdery mildew (7.9%), borers (6.8%), and drought (4.4%) also were significant. For deciduous (sub-) Mediterranean oaks, defoliators (12.6%) were the most common damaging agents, followed by borers (8.4%), gallmakers (7.1%) and drought (4.9%). Drought was by far the most important damaging agent for evergreen oaks (40.3%), but also borers (12.9%), decay and root rot fungi (9.4%) and defoliators (4.7%) had a large impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (13.2%), followed by *Viscum album* (7.6%) and needle cast/needle rust fungi (6.1%). For Norway spruce, red deer (5.8%) and mechanical/vehicle damage (5.3%) were most important. Defoliators were causing most damage (25.0%) on Austrian pine trees, but *V. album* (13.1%), needle cast/needle rust fungi (9.6%), blight (6.3%) and drought (4.9%) also caused considerable damage. Mediterranean lowland pines were mostly affected by drought (27.7%) and defoliators (15.7%).

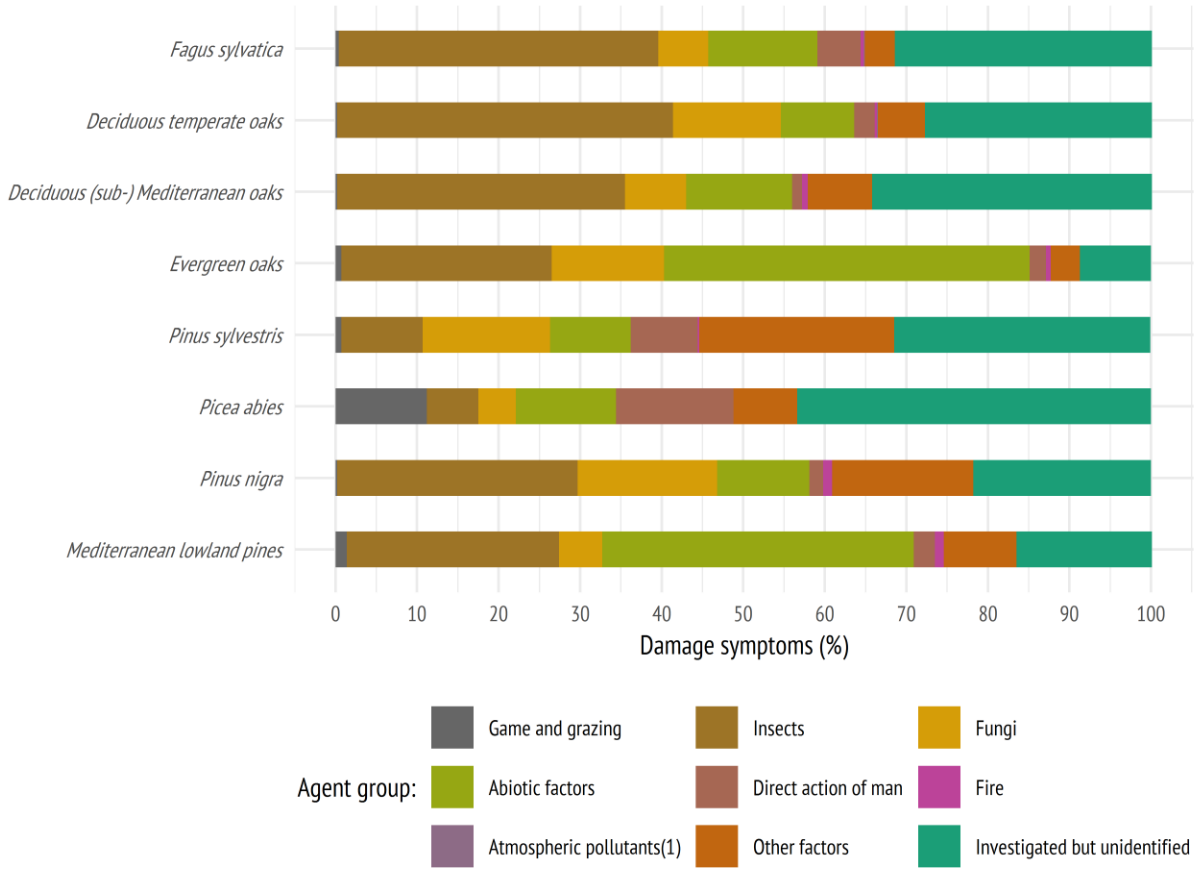

Figure 7-5: Percentage of damage symptoms by agent group for each main tree species and species group. (1) Visible symptoms of direct atmospheric pollution impact only

Regional importance of the different agent groups

Damage caused by insects in 2018 was observed on 1 850 European Level I plots, which corresponds to 34% of all plots with damage assessments. With a few exceptions (Sweden, Denmark, northern Germany and Romania), a high proportion of plots in each country was affected by this agent group throughout Europe.

Damage caused by abiotic agents was reported from 1 854 Level I plots (34%) throughout Europe. Countries most affected by abiotic agents were Spain, Slovenia, and Montenegro.

The agent group 'Fungi' was responsible for damage on 1 321 European Level I plots (24%) in 2018, and was frequently occurring in many countries, most notably in Estonia, Slovenia, Montenegro, parts of Serbia, Poland, Bulgaria and Spain. Very low occurrence of damage by fungi was observed in Turkey, Romania, Switzerland and Greece.

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 1 026 plots (19%), and was most frequently occurring in parts of eastern Europe and southern Germany.

Damage caused by game and grazing in 2018 was most frequently observed in the Baltic countries, Hungary and Spain, and in parts of Poland and Germany. In total, 280 Level I plots (5%) had trees damaged by this agent group.

There were only 51 plots (1%) with damage inflicted by fire, most of them located in Spain.

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

Dead trees and causes of death

There were only 711 (0.7%) dead trees in the damage assessment 2018. The main cause of death to both conifer and broadleaved trees were abiotic factors (Figure 7-6). For the broadleaves, fungi and fire were also major causes of death, while for conifers insects and fungi were also of importance. A large part of the damaging agents causing tree death could not be identified with certainty.

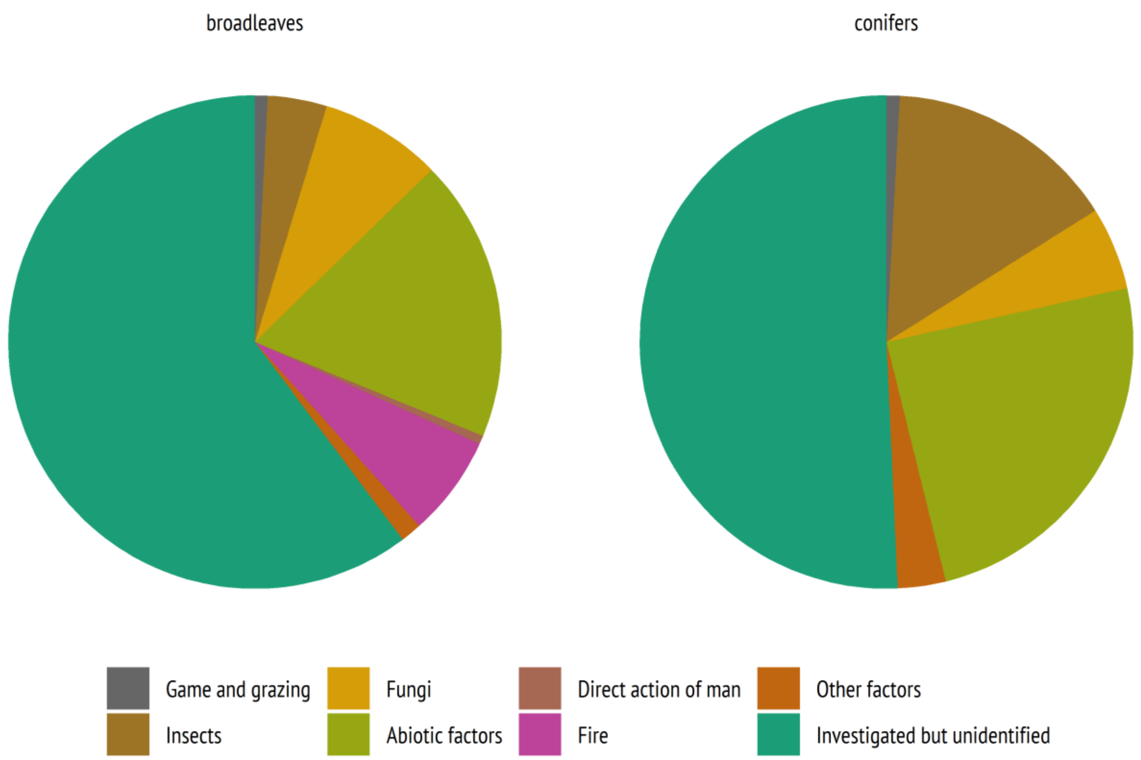

Figure 7-6: Percentage of damaging agent groups causing death of broadleaved and coniferous trees in 2018 (n = 711)

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

7.4 Conclusions

In 2018, the mean defoliation was somewhat higher than in 2017, increasing by 0.7% to 22.9% for broadleaved and by 1.0% to 21.3% for coniferous species. There was a slight increase in mortality in 2018.

Based on the data in the past 20 years, the defoliation has been increasing for Norway spruce and Scots pine, with only small annual deviations from the trend. In contrast to other species and species groups, direct action of man and game and grazing were the most important damaging agents. A large share of damage symptoms could not be assigned to specific damage agents for Norway spruce, complicating the interpretation of defoliation assessments. Damage in Scots pine was mostly caused by management (competition) and biotic factors (*Viscum album* and needle cast/needle rust fungi).

Defoliation of beech increased slightly in 2018. The major identified causes of damage on beech in 2018 were mining insects and defoliators.

Deciduous temperate oaks and Austrian pine had the strongest increase in defoliation in 2018. Defoliators were the most important damaging agents for both.

After an increase of defoliation in 2017, crown condition improved in both Mediterranean lowland pines and evergreen oaks in 2018. However, evergreen oaks still have the highest defoliation of all major species and species groups. The major cause of damage for both species groups was drought.

The average number of recorded damage symptoms per assessed tree was substantially lower for conifers than for broadleaves. Insects, abiotic causes and fungi were the most common damage agent groups, comprising altogether more than half of all damage records.

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8 NEWS FROM THE ICP FORESTS SCIENTIFIC COMMITTEE

Marcus Schaub, Lars Vesterdal, Marco Ferretti, Kai Schwärzel, Pasi Rautio, Bruno De Vos

The Scientific Committee (Sci Com) in its new constellation was approved by the ICP Forests Task Force in 2018. The new committee members are Marcus Schaub (Switzerland, WSL, Chair of the Sci Com), Lars Vesterdal (Denmark, UCPH, Vice-chair of the Sci Com), Marco Ferretti (Switzerland, WSL, Chair of ICP Forests), Kai Schwärzel (Germany, Thünen, Head of the Programme Co-ordinating Centre), Pasi Rautio (Finland, Luke, Chair of the Expert Panel on Foliage and Litterfall) and Bruno De Vos (Belgium, INBO, Chair of the Expert Panel on Soil and Soil Solution) (Figure 8-1, from left to right). Women and participants from institutions located in Southern and Eastern Europe are currently underrepresented in the Scientific Committee. Thus, the committee follows an "everybody welcome policy" and encourages each of the Expert Panels to appoint one of their members to join the Scientific Committee to actively contribute to driving the science within the ICP Forests program forward. As a basis for its collaboration with the Programme Coordinating Centre, the Programme Coordinating Group and the Expert Panels, the Scientific Committee developed a working paper, comprising the history, organization, strategic aims and an implementation plan, which is divided into continuous and temporal tasks.

Organization

The Scientific Committee has a mandate from the Task Force and constantly interacts with the Programme Coordinating Centre as well as with the Programme Coordinating Group, providing advice and suggesting (strategic) priorities in order to promote and advance science within ICP Forests (Figure 8-2). The Scientific Committee is supported by an annually designated Conference Panel, which takes part in the organization of the annual scientific conference and strengthens the Scientific Committee in its tasks and contributes to the review process of the submitted abstracts. For internal communication and meetings, the Scientific Committee proposes one annual meeting overseeing and discussing possibilities for cooperation, possible applications and joint evaluations with other programs. This meeting is usually placed back to back with the annual Programme Coordinating Group meeting in Berlin in the fall.

Strategic aims

ICP Forests provides the Working Group on Effects of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) with scientific knowledge on the effects of air pollution and other environmental factors on forest ecosystems. The main aim of the Scientific Committee is therefore to promote and support the ICP Forests scientific activities. The main concern is scientific impact. The Scientific Committee works to promote the publication process with emphasis on data papers and integrative studies, to increase the impact and output from the scientific conference, and to intensify the collaboration with external programs and scientists. The Scientific Committee helps to develop the above topics as an integrated part of the activities in close collaboration with the Programme Coordinating Centre and the Programme Coordinating Group.

Publication strategy and outreach

The Scientific Committee aims at supporting the ICP Forests community in publishing ISI data papers, to enable ICP Forests data being cited with a Digital Object Identifier (DOI). The Expert Panel chairs as well as the internal and external data users should be supported towards integrative, large-scale studies across different networks, such as EANET, NAFSC, ILTER, ICOS, ENFI, EFI, EEA, TERN, AnaEE and others. Participating countries should be encouraged in publishing national scientific papers (including data papers), which complement and support the ICP Forests dissemination efforts. A publication process for integrative scientific papers may be developed by preparing a list of proposed evaluation studies using a hypothesis-driven framework and targeting highly ranked journals.

Figure 8-1. Current members of the ICP Forests Scientific Committee

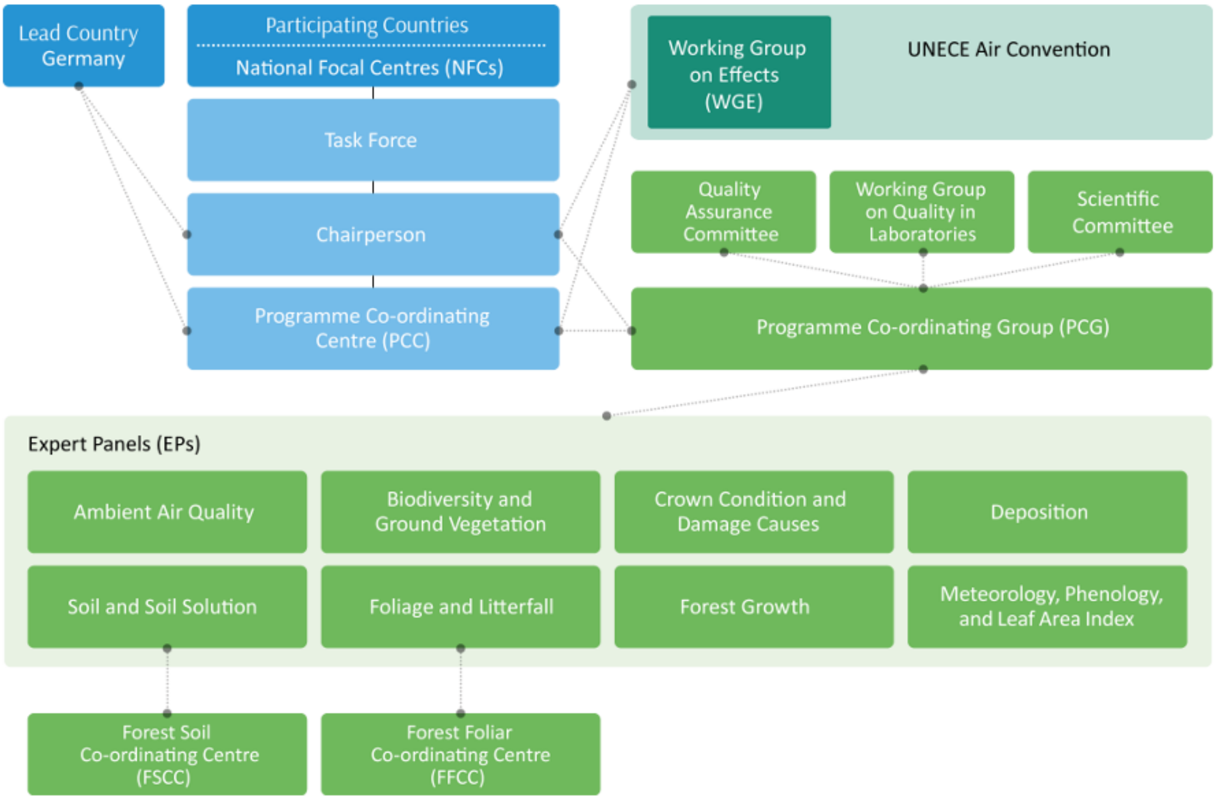

Figure 8-2: The Programme Task Force is the highest body of ICP Forests and it represents all participating countries. National experts are organized in Expert Panels and Working Groups, which ensure the continuous development and harmonization of the monitoring methods and contribute to data evaluations (Source: ICP Forests web page).

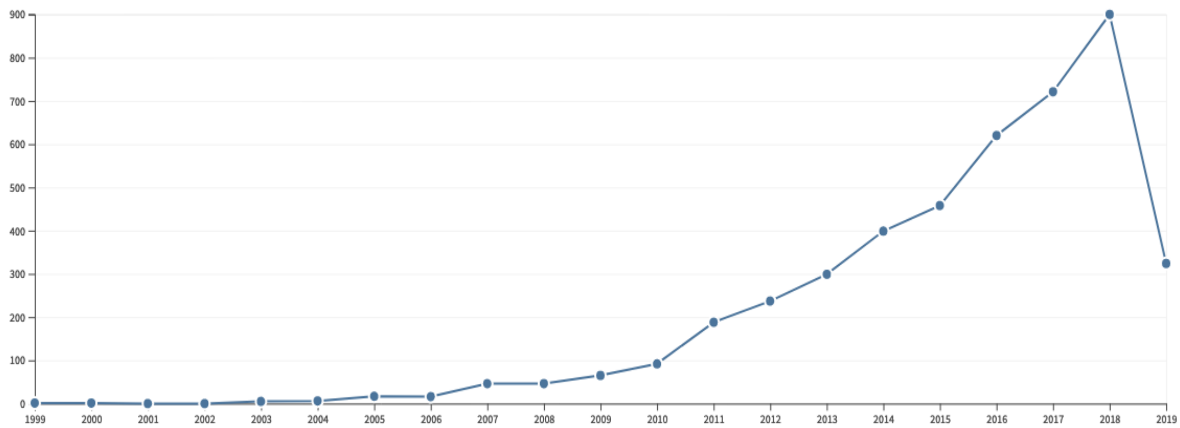

Figure 8-3: Sum of times for ICP Forests ISI publications cited per year (Source: Web of Science on 4 April 2019 for ResearcherID F-7626-2019)

The Scientific Committee has recently registered ICP Forests with a ResearcherID of Web of Science, allowing a dynamic search and statistical analyses of published ICP Forests ISI publications. You may access Web of Science at http://apps.webofknowledge.com and enter F-7626-2019 for "Author Identifiers" to access all ICP Forests publications and respective statistics. Among others, Web of Science provides an overview of the temporal development in annual citation rate (Figure 8-3).

This and other enlightening statistics are made available by manually adding the ICP Forests ISI publications listed at the ICP Forests publication web page, to the ResearcherID profile F-7626-2019 of Web of Science. This database will be continuously maintained to further provide dynamic statistics about the ISI publications of ICP Forests, to foster the publication process and to facilitate the annual reporting towards national partners and stakeholders.

Furthermore, the Scientific Committee explores possibilities to make all ISI ICP Forests publications from Web of Science available in one file (txt format), which then can be easily imported into standard, personal literature data bases as offered by e.g. EndNote or ReadCube.

The Scientific Conferences

The ICP Forests Scientific Conference is taking place every year, usually back to back to the Task Force meeting (traditionally held) in May, providing a broad audience from all over Europe and beyond with the latest results from long-term forest monitoring research. The Scientific Committee serves as the scientific organizer of the annual conference and decides, in collaboration with the Programme Coordinating Group, on further scientific meetings or changes in meetings. The Scientific Committee wishes to attract more PhD students and postdocs to the Scientific Conference as well as into the programme.

The 8th Scientific Conference took place in Ankara on 11-12 June 2019. The scope of the conference was inspired by the recent drought and other extreme events occurring across Europe in 2018. The focus of the conference was therefore on forest ecosystem effects from recent and past extreme events caused by drought, heat, storms, frost and flooding. With "Trends and events - Drought, extreme climate and air pollution in European forests" we aimed to promote the extensive ICP Forests data series to combine novel modeling and assessment approaches and integrate long-term trends with extreme weather events across European forests. We particularly invited researchers using ICP Forests data in their evaluations and modelling approaches. Contributions on new advances based on airborne or satellite data were particularly welcome in order to stimulate the exchange of ideas, know-how and data from long-term monitoring and novel modelling approaches for air borne approaches. The main session topics were

- Effects of drought and other extreme weather events on processes and forest ecosystem functioning
- Long-term trends in forest ecosystem processes as affected by drought or other extreme weather events
- Air pollution effects on forest ecosystem functioning under extreme and/or prolonged unfavorable climate and weather

We welcomed Svein Solberg from the Norwegian Institute of Bioeconomy Research (NIBIO) who was giving the key note on combining ICP Forests data with airborne data. The title of his presentation was "Satellite remote sensing: An extension for ICP-Forests?".

Collaboration with external programs and experts

It is in the very interest of ICP Forests to involve other monitoring and research programs to promote integrated and cross-sectorial evaluations and to intensify the networking with other long-term ecosystem programmes such as EANET, NAFSC, ILTER, ICOS, ENFI, EFI, EEA, TERN, AnaEE and other ICPs of the UNECE-WGE.

On 12 April 2019, a joint expert workshop between ICP Forests and ICP Vegetation - hosted by Marco Ferretti – took place at the Swiss Federal Research Institute WSL. Invited members of both ICPs discussed results and ideas on assessing and estimating ozone impacts on forest vegetation including opportunities for closer co-operation.

- During the XXV IUFRO World Congress, which took place in Curitiba, Brazil (http://iufro2019.com/) from 29 September to 5 October 2019, ICP Forests hosted a double session on Long-Term Forest Monitoring Networks for Evaluating Responses to Environmental Change. This session was organized by Marcus Schaub, Hiroyuki Sase (EANET), Lars Vesterdal and Marco Ferretti and aimed to attract scientists, managers and stakeholders who were keen to understand large-scale, long-term effects of rapidly changing environmental drivers on forest ecosystems, to advance forest monitoring systems from local to global scale. The session offered the opportunity to present latest research findings, address methodological issues, and outline solutions based on the comprehensive data series from long-term forest monitoring networks world-wide, such as ICP Forests, EANET, ICOS, ILTER, ENFIN, TERN, AnaEE and others. A further objective was to provide a platform for networking and cooperation to support future synthesis studies across monitoring networks. Presentations on new advances based on airborne or satellite data were particularly welcome. The double session comprised 21 oral and 9 poster presentations which were divided into the following sub-sessions:

- Monitoring to explain and mitigate impacts of environmental change
- Outcomes of monitoring
- Monitoring infrastructures

The Scientific Committee was proud to have established an attractive programme on Long-Term Forest Monitoring Networks for Evaluating Responses to Environmental Change at the XXV IUFRO World Congress and is keen on promoting our programme and considerable achievements.

Temporal tasks / Outlook

Besides the strategic and continuous tasks as indicated above, the Scientific Committee supports temporal tasks and ad-hoc initiatives from the ICP Forests community. For example:

- 2018 drought effects - How to assess current, post-drought and legacy effects. Several national initiatives (e.g. by Katrin Meusburger and Peter Waldner) are currently being conducted.
- 2020 – 2025, attempt to develop repeated soil survey on Level I, led by Bruno De Vos
- Support follow-up study by Sietse van der Linde on environment and host as large-scale controls of ectomycorrhizal fungi (see Van der Linde et al. 2018, Nature). ICP Forests, with its participating countries, will provide data, samples, infrastructure and labs.
- Initiative of Manuel Nicolas on how to address challenges for the Level II monitoring in the next decades.

The Scientific Committee thanks the ICP Forests community for its long-term efforts and is keen on helping to put the ICP Forests achievements, such as infrastructure, data and expertise into more value.

Part C

NATIONAL REPORTS OF PARTICIPATING COUNTRIES IN ICP FORESTS

9 NATIONAL REPORTS OF COUNTRIES PARTICIPATING IN ICP FORESTS

All participating countries in ICP Forests were invited to submit summary reports on their ICP Forests activities instead of reports only on their 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

Silvia Ferrer, Ministry of Environment, Agriculture and Sustainability, Govern d'Andorra

Report on 2018 national crown condition survey

The assessment of crown condition in Andorra in 2018 was conducted on 12 plots on the national 4x4 km grid. A total of 118 *Pinus sylvestris*, 139 *Pinus uncinata*, 5 *Betula pendula* and 27 *Abies alba* trees were sampled.

Results for 2018 show that the forest condition has slightly recovered, continuing the improving tendency registered during the period of 2013–2016.

For all species, most of the trees were classified in defoliation and discolouration classes 0 and 1. The favourable climatic conditions in the winter and spring months in 2018 could explain the increase in the defoliation and damage classes 0.

Defoliation varied depending on the species. Nearly 55% of *Pinus sylvestris* and *P. uncinata* trees showed non-defoliated individuals, respectively, whereas 80% of the *Betula pendula* individuals showed slight defoliation. Only *Abies alba* showed 100% non-defoliated individuals.

With regard to discolouration, the large majority of trees of all species except *Abies alba* was classified in the slight discolouration class. Most of the *Abies alba* trees were classified as non-discoloured (88.9%).

Damage was caused by several casual agents like wind, snow, falling trees, biological agents as fungus *Cronartium flaccidum* or the insects *Thaumetopoea pityocampa*, *Ips acuminatus* and *Phaenops cyanea*, rots and lightning scars, which all in all affected 16.9% 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 survey was executed on 69 plots on a 4x4 km grid. Eight plots are part of the transnational 16x16 km grid. In total, crown condition assessments were performed on 804 broadleaved trees and 677 conifers (n=1481). The main species are *Pinus sylvestris* (n=498), *Quercus robur* (n=359), *Pinus nigra* subsp. *laricio* (n=170), *Fagus sylvatica* (n=110) and *Quercus rubra* (n=91). A subset with 'other broadleaves' consists of 14 species and 244 trees. Common species in this group are *Castanea sativa*, *Alnus glutinosa*, *Fraxinus excelsior*, *Betula pendula*, *Acer pseudoplatanus*, *Populus* sp. There are almost no 'other conifers' (n=9).

As regards to Level II activities a study at the national level was started in order to elucidate the role of tree pollen in throughfall chemistry. Branches with male reproductive structures, i.e. flowers (beech, pedunculate oak) or cones (Scots pine, Corsican pine) were collected during spring and incubated in a greenhouse to sample fresh pollen. Exploratory tests with commercially available birch pollen in cooperation with Sciensano were started. An analysis of long-term (20 years) data on throughfall, litterfall and pollen air concentrations was carried out. A proposal was worked out to upscale this study in cooperation with other scientists, with currently 11 European countries involved and with additional analyses (pollen load using filtration of throughfall samples, DOC characterization).

Major results/highlights

The mean defoliation of all trees in the Level I survey was 24.6%, and 22.8% of the trees were rated as damaged. The share of healthy trees was low (7.7%). A majority of trees was classified in defoliation class 1 (69.5%). Defoliation was moderate in 19.5% of the sample trees. The proportion of trees with severe defoliation was 2.2% and 1.1% of the trees had died. Defoliation was high in the 'other broadleaves', with 35.3% of the trees in defoliation classes 2-4. Defoliation was also higher than the mean in *Pinus nigra* and *Fagus sylvatica*, with 32.4% and 25.4% of the trees classified as being damaged. Lower levels of damage were observed in *Quercus robur* (22.8%), *Pinus sylvestris* (15.1%) and *Quercus rubra* (11.0%).

Mean defoliation increased compared to the last survey. A significant increase in defoliation was registered in *Fagus sylvatica* (+4.0 percentage points) and the 'other broadleaves' (+4.3 percentage points). In *Quercus robur* (+0.4 percentage points), *Pinus sylvestris* (+0.7 percentage points) and *Pinus nigra* (+0.5 percentage points) no significant changes were registered. *Quercus rubra* is the only species with a significant decrease in defoliation (-1.8 percentage points).

Both *Fagus sylvatica* and *Quercus robur* showed high seed production. Seeds were observed on 97.3% of *F. sylvatica* and 78.3% of *Q. robur* trees. Moderate to high fructification was recorded on 39.1% and 22.0% of the trees.

Damage caused by defoliators decreased; 8.9% of *Quercus robur* showed moderate to severe insect defoliation (-5.7 percentage points). At the same time, heavy mildew infection (*Microsphaera alphitoides*) was observed less frequently. Mildew infection caused moderate to severe discolouration on 3.1% of *Q. robur* (-4.9 percentage points).

Spring and summer were warm and dry. Symptoms of drought were observed on ground vegetation and shrubs but also on broadleaved sample trees (*Fagus sylvatica*, *Acer pseudoplatanus*, *Castanea sativa*, *Betula pendula*...). Heat and drought caused dieback of conifers outside the plots, mostly in combination with bark beetle attacks or fungal infestations (*Picea abies*, *Abies* sp., *Pinus* sp.). On January 18th a heavy storm caused damage in several plots.

In 2014 a survey was started to study the condition of *Fraxinus excelsior* and the impact of *Hymenoscyphus fraxineus*. 252 common sample trees were assessed in 29 plots, partly on the Level I grid. Mean defoliation increased from 28.8% in 2014 to 45.3% in 2018, the share of damaged trees from 32.1% to 60.3%. At the start, 6.7% of the trees showed more than 60% defoliation. In 2018, the proportion of trees with severe defoliation amounted to 28.6%. Since the start of the survey 10.7% of the ash trees have died.

Long-term data on atmospheric depositions, soil solution chemistry and foliar chemistry collected in 5 Flemish Level II plots were analysed (trends, exceedance of critical loads and levels) and published as a PhD-thesis.

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

Neirynck J, Verstraeten A (2018) Variability of ozone deposition velocity over a mixed suburban temperate forest. Frontiers in Environmental Science 6, 82, https://doi.org/10.3389/fenvs.2018.00082

Verstraeten A (2018) Evolution of soil solution chemistry in temperate forests under decreasing atmospheric deposition in Flanders. PhD-thesis, Ghent University, Faculty of Bioscience Engineering, Ghent, Belgium, 210 p.

Verstraeten A, Gottardini E, Vanguelova E, Waldner P, Bruffaerts N, Nussbaumer A, Neumann M, Clarke N, Hansen K, Rauti, P, Ukonmaanaho L (2018) Establishing a link between pollen dispersal, seed production and throughfall dissolved organic carbon (DOC) flux in temperate forests. ICP Forests 7th Scientific Conference, Riga, Latvia, 21–23 May 2018

Sioen G, Verschelde P, Roskams P (2018) Bosvitaliteitsinventaris 2017. Results of the crown condition survey (Level I). Research Institute for Nature and Forest, Report 2018 (41). INBO, Brussels (in Dutch). ISSN: 1782-9054,DOI:doi.org/10.21436/inbor.14178308 https://pureportal.inbo.be/portal/files/14528853/SioenVerscheldeRoskams_2018_Bosvitaliteitsinventaris2017.pdf

Outlook

The Level I and the Level II programmes will be continued, as well as the additional survey on the condition of *Fraxinus excelsior*.

Peter Roskams, Geert Sioen, Arne Verstraeten (INBO)

Belgium Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2018, data were collected in 8 plots for Level II/III and in 44 plots for Level I.

Major results/highlights

The species began their season of vegetation at normal dates, except for larch and hornbeam, which had a late budburst because of the coldness in March. The spring climate was favorable for trees. On the other hand, they had to face a marked heat wave and drought in July. The effects of drought on the network trees were not felt because the plots are on adapted conditions of climate/soil. Nevertheless, outside the network, trees on southern slopes or on shallow soils may have lost their foliage as early as August, blush or die. Climatic trends have normalized in August but soil water reserves have been slowy recovering. In general, all species have abundantly fructified. More particularly, here are some tendencies for the followed species:

- Douglas-firs are still affected by Swiss rust which causes needle loss. Their average defoliation rate is currently 35%.
- The degraded status of beeches is maintained with an average of 46% defoliation.
- Since 2014, oaks have benefited from a good decrease in average defoliation (-6%). The values for pedunculate and sessile oaks are respectively 25% and 12% defoliation. Spring damage due to defoliating caterpillars has remained low in 2018 but the number of affected trees is increasing slightly, suggesting that caterpillar populations are beginning to expand.
- The health status of spruces, which was usually fairly stable, has deteriorated since 2017. Their crowns reach 38% defoliation. This is certainly due to the heat wave. In addition Wallonia has suffered a serious crisis due to the proliferation of the *Ips typographus*.

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 Forests 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.

An analysis of the Level I, Level II, and Level III network data available since 1989 was also published (in French): Titeux H, Jonard M, Bay E, Laurent C, Mertens P, Ponette Q (2018). L'évolution de la santé des forêts wallonnes-Principaux enseignements des réseaux de monitoring "ICP Forests". Forêt Nature 147: 48-60.

The ICP Forests data wer also used in a publication aiming at proving the greater resilience of diversified forests to future climate change-induced stress:

Sousa-Silva R, Verheyen K, Ponette Q, Bay E, Sioen G, Titeux H, Van de Peer T, Van Meerbeek K, Muys B (2018). Tree diversity mitigates defoliation after drought-induced tipping point. Glob Change Biol 24(9):1-12. doi: 10.1111/gcb.14326

Bulgaria

National Focal Centre

Genoveva Popova, Executive Environment Agency (ExEA)

Main activities/developments

The Level I forest monitoring network includes 160 permanent sample plots, grouped in 10 regions, and cover the entire forest territory of the country. The Level II forest monitoring programme is implemented in four permanent sample plots, one of which is the core-plot (SP0001 Vitinia).

The Forest monitoring programme in Bulgaria operates in the frame of the National System for Environmental Monitoring (http://eea.government.bg/en/nsmos/index.html).

Major results/highlights

The 2018 Level I crown condition survey was carried out on 160 permanent sample plots. The observation covered 2427 coniferous trees, representing the four main coniferous tree species – silver fir (*Abies alba* Mill.), black pine (*Pinus nigra* Arn.), Norway spruce (*Picea abies* (L.) Karst) and Scots pine (*Pinus sylvestris* L.) and 3169 deciduous trees, representing nine of the deciduous tree species in the country, including common beech (*Fagus sylvatica* L.), Oriental beech (*Fagus orientalis* Lipsky), Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus frainetto* Ten.), sessile oak (*Quercus petraea* (Matt.) Liebl.), Northern red oak (*Quercus rubra* L.), European hornbeam (*Carpinus betulus* L.), Sweet chestnut (*Castanea sativa* Mill.) and large-leaved linden (*Tilia platyphyllos* Scop.), or 5596 sample trees in total. The results show that both deciduous and coniferous tree species maintained about the same health status compared to the previous year. The share of healthy (not defoliated) and slightly defoliated trees was 68.2%. The trend of deciduous tree species being in better condition compared with coniferous continued in 2018 - 78.2% of deciduous trees and 55.0% of coniferous showed defoliation of up to 25%. No mass attacks by insect pests and fungal diseases were detected at that stage. The presence of the root fungus (*Heterobasidion annosum*) was determined in the Scots pine and black pine stands. The phytopathogens *Diplodia sapinea* and *Dothistroma pini* were also a serious threat. The presence of necroses, caused by *Nectria* spp. and less frequently by *Ascodichaena rugosa*, was determined in the common beech stands. Attacks by *Orchestes fagi*, *Mikiola fagi* and *Hartigiola annulipes* were also recorded. Small damages, caused by geometer and tortrix moths (*Geometridae* and *Tortricidae*), were found in the monitored oak stands (*Quercus cerris*, *Q. frainetto*, *Q. petraea* and *Q. rubra*). Hypoxylon cancer (*Hypoxylon mediterraneum*) was determined in part of the pure Turkey oak stands.

The assessment of the monitored stands over the last 5 years (2014-2018) has revealed an insignificant decrease in the number of healthy and slightly defoliated trees. Regarding the deciduous tree species, there is a tendency towards improvement of the condition with respect to this indicator.

At Level II, in 4 field stations, beech, Hungarian oak, spruce and mixed spruce-fir stands were monitored. The observations started in 2003. Stress factors, biological and chemical condition were assessed.

Stress factors I

For some years, ozone was a stress factor in the region of the beech and mixed spruce-fir stands. On average for the last 5 years, the respective value for forest protection (AOT40 April-September) was exceeded by 1.8 times as the highest value determined in 2015 (45770 µg/m^3.h). The accumulated ozone exposure over the threshold of 40 ppb (AOT40 April-September) in the spruce-fir stand was 2.5 times higher than the determined critical level for forest protection. The maximum value was also determined in 2015 (72661 µg/m^3.h). Although ozone remained the major stress factor in these areas, a gradual decrease of the AOT40 indicator has been determined over the past 3 years. In 2017, an increase in the depositions of sulfate sulfur, ammonium nitrogen, nitrate nitrogen and chlorides was determined in the area of the monitored beech stand. Regarding the base cations more sodium and magnesium were deposited, and of the heavy metals – zinc. A trend of increasing acidity of precipitation in the Hungarian oak stand has been observed since 2014. The respective values were within the acidic range (pH values from 5.05 to 5.5), similar to the values, determined during previous surveys. In 2017, greater amounts of nitrogen (nitrate and ammonium), chlorine, sulfate sulfur and phosphates were deposited in the area of this stand. Regarding the base cations more depositions of potassium and of the heavy metals copper and aluminum were found. Compared to 2016, in the area of the spruce-fir stand an increase in the deposition of some ions with acidic functions such as sulphates, nitrates, nitrites and chlorine, some base cations (magnesium and sodium) and some heavy metals (zinc and aluminum) was determined.

Biological condition I

The results of the annual health status assessment of the sample trees and stands in relation to the "defoliation" indicator show that the number of healthy and slightly damaged trees prevailed over the last 5 years. Phenology observations in the beech stand of the sample core plot have been carried out since 2011. The duration of the vegetation period was determined for the period 2011 – 2017, and the respective values are 190, 205, 178, 195, 204, 215, and 206 days. The floristic composition and phytocenotic structure of the shrub-grass synusiae in the plant communities of different associations, number and age structure of the undergrowth layer, have been determined every 5 years in Level I plots and every 2 years in Level II plots since 2003. The reported changes of the cover and occurrence of species during the monitoring period varied around the average values for the past 10 years, suggesting that these variations could be assessed as ecotopic and phytocyclic fluctuations of the vegetation.

Chemical condition I

The results of the soil solution analysis in the beech stand showed the mobility of water-soluble forms of the macro- and microelements which led to soil degradation. High manganese content in the soil solution was determined. The low mineralization of the soil solution was confirmed in the mixed spruce-fir stand. The content of macro- and microelements in leaves/needles has been assessed every two years since 2003. The accepted regional ranges for normal functioning of monitored tree species and ICP Forests criteria were used for the assessment. Based on assessments during the period 2003 - 2017, it can be concluded that balanced nutritional status prevailed.

In 2018, a third ten-year soil survey cycle in the Level I sample plots was launched. In 2019, a third forest soil survey will be carried out in Level II plots according to the ICP Forests Manual.

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

Kuzmanova R (2015) Phenological observations of Fagus silvatica L. during 2012 in the Balkan range, Forestry ideas, Vol. 2. №1 (49) ISSN,1314-3905 (print), ISSN 26-03-2996 (online), 115-122.

Mullett MS, Adamson K, Braganca H, Bulgakov TS, Georgieva M, Drenkhan R (2018) New country and regional records of the pine needle blight pathogens Lecanosticta acicola, Dothistroma septosporum and D. pini. Forest pathology, Wiley Online Library. doi/abs/10.1111/efp.12440.

Pavlova E, Pavlov D, Doncheva M, Kuzmanova R, Kadinov G (2016) Station Vitinya. Beech ecosystem. Monitoring of abiotic and biotic indicators 2013-2014. Publishing house" c. 64., ISBN.978-954-749-109-0.

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Simov N, Grozeva S, Langourov M, Georgieva M, Mirchev P, Georgiev G (2018) Rapid expansion of the Oak lace bug Corythucha arcuata (Say, 1832) (Hemiptera: Tingidae) in Bulgaria. Historia naturalis bulgarica, 27, 51-55.

Tzvetkova N, Malinova L, Doncheva M, Bezlova D, Petkova K, Karatoteva D, Venkova R (2016) Soil Contamination in Forest and Industrial Regions of Bulgaria. In book: Soil

Contamination - Current Consequences and Further Solutions Chapter: Chapter 7, Publisher: Intech Editors: Marcelo L. Larramendy and Sonia Soloneski, ISBN 978-953-51-4874-6, DOI: 10.5772/64716.

Zaemdzhikova G, Markoff I, Mirchev P, Georgiev G, Georgieva M, Nachev R, Zaiakova M, Dobreva M (2018) Expansion zone and rate of the pine processionary moth (Thaumetopoea pityocampa) in Bulgaria. Silva Balcanica, 19(3), 15-23.

Outlook

The programme for the monitoring of forest ecosystems (Level I and Level II) in Bulgaria is permanent and is operationalized as part of the National System for Environmental Monitoring. Regarding the future developments of the infrastructure, a gradual extension of the Level II network is being undertaken. The aim is to cover all regions in which Level I observations are carried out (a total number of 10). In addition, the four sample plots for intensive forest monitoring are in the process of integration with the long-term network for ecosystem research in Bulgaria (LTER-BG).

Croatia

National Focal Centre

Nenad Potočić, Croatian Forest Research Institute

Main activities/developments

The NFC Croatia organized the 14th Ozone Intercalibration Course from 10 to 13 September 2018 in Poreč.

Major results/highlights

Level I

Ninety-nine sample plots (2 376 trees) on the 16 x 16 km grid network were included in the survey 2018 - 2014 broadleaved trees and 362 conifers.

The percentage of trees of all species within classes 2-4 is relatively stable through the years - in the year 2018 it was 30.8%. Traditionally broadleaves have lower defoliation; in 2018 the percentage of broadleaved trees within classes 2-4 was 27.9%, while it was 47.0% for conifers. There is more variation in conifers also: the annual differences are up to 5 percent.

Most defoliated tree species in Croatia in 2018 were *Fraxinus angustifolia* (66.6% of trees in classes 2-4) and *Pinus nigra* (64.7%). The crown condition of black pine varies a lot from year to year, and the condition of narrow-leaved ash deteriorates constantly: from 8.8% in 2008 to 75.0% in 2017. In 2018, however, a small improvement was recorded. Along with dry years, and the presence of *Stereonychus fraxini*, also the increased presence of *Hymenoschyphus fraxineus* (*Chalara fraxinea*) in the last years seems to be a factor causing increased deterioration of ash health. Although the percentage of *Abies alba trees* in classes 2-4 is below 50% in 2018, it is still within the top three of the most damaged tree species in Croatia.

The largest number of damages was recorded on leaves (40.4% of all recorded damage), followed by branches, shoots and buds (33.8%), and finally on the trunk and butt end (25.7%). Most of tree damage is caused by insects (27.5% of all damage), especially defoliators (14.6%). Next are abiotic agents with 12.4% of all damage. In 2018 drought was not a major damage factor (2.4% compared to 4.7% in 2017). Damage caused by fungi accounted for 6.8% of all damage, while direct human activity accounted for 4.7% of all damage to forest trees. Most of damage (62%) falls into extent category 1 (0-10%).

Level II

Annual defoliation values on our intensive monitoring plots depend both on local climate parameters and biotic factors. Significant damage from beech leaf-mining weevil – *Rhynchaenus fagi* was recorded on plot 105. Dieback caused by *Lophodermium* sp. fungi was recorded on Aleppo pine trees on plot 111.

A grave problem for our pedunculate oak stands is *Corythuca arcuata*, and the damage in the form of leaf chlorosis as the consequence of oak lace bug attack was found on our plot 109. Starting from 2015, these damage symptoms are found regularly on all trees.

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

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

Potočić N, Seletković I, Jakovljević T, Marjanović H, Indir K, Medak J, Anić M, Zorić N, Ognjenović M (2018) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2017. godinu. The damage status of forest ecosystems in Croatia – a report for 2017. Hrvatski šumarski institute/Croatian Forest Research Institute. Jastrebarsko, Croatia. www.icp.sumins.hr

Outlook

Sampling at Level II plot 105 (Zavižan) is planned to be supplemented with deposition, lysimetry, growth and litterfall samplers in the next three to four years, starting in 2019.

Croatia is going to supply selected Level II monitoring data to the European Commision following the adoption of the new National Emission Ceilings Directive.

Cyprus

National Focal Centre

Andreas Christou, Ministry of Agriculture, Rural Development & Environment, Research Section – Department of Forests

Report on 2018 national crown condition survey

The annual assessment of crown condition was conducted on 15 Level I plots during the period May – June 2018. The assessment covered the main forest ecosystems of Cyprus and a total of 365 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 (2017) shows a decrease of 4.8% in class 0 (not defoliated) and 5.2% in class 1 (moderately defoliated). An increase of 6.7% in class 2 (severely defoliated), 1.3% in class 3 and 1.9% in class 4 (dead) has been observed.

From the total number of trees assessed (367 trees), 15.5% of them were not defoliated, 51.0% were slightly defoliated, 28.6% were moderately defoliated, 3.0% were severely defoliated and 1.9% were dead.

In the case of *Pinus brutia*, 13.4% of the sample trees showed no defoliation, 48.4% were slightly defoliated, 32.7% were moderately defoliated, 3.6% were severely defoliated and 2.0% were dead. For *Pinus nigra*, 25.0% of the sample trees showed no defoliation, 66.7% showed slight defoliation and 8.3% were moderately defoliated. For *Cedrus brevifolia*, 28.0% of the sample trees showed no defoliation, 60.0% were slightly defoliated and 8. 0% were moderately defoliated.

A discoloration has been observed as well. From the total number of trees assessed (367 trees), 88.6% of them were not discolorated and 11.4% were slightly discolorated.

As in the previous assessment (2017), the major abiotic factors causing defoliation in some plots during 2018 were the combination of the climatic with the edaphic conditions which resulted to secondary attacks by *Leucaspis* spp. and defoliator insects to a large number of the assessed trees.

Czech Republic

National Focal Centre

Vít Šrámek, Forestry and Game Management Research Institute (FGMRI)

Main activities/developments

A joint expert seminar with Slovak counterparts from the National Focal Centre was held on May 30 – June 1, 2018 in the Malá Fatra National Park in Slovakia. The agenda was, among others, the results of monitoring in the ICP Forests programme and their comparison between the two countries.

Major results/highlights

In 2018, increased mortality of forest tree species continued as a consequence of adverse climate development in the growing season (high temperatures and low amount of precipitation), related spread of various biotic pests and as a result of damaging winds. An increase in the proportion of trees with severe defoliation (class 3) was also found to continue in the majority of conifer and broadleaved species in all age categories. As a consequence of the bark beetle calamity there appeared extensive clearings mainly in northern Moravia affecting also several monitoring plots. The occurrence of pine dieback followed by the attack of various biotic pests was high at medium and lower altitudes. In warmer regions broadleaved stands were infested by leaf-eating insects to a greater extent, and in ash (*Fraxinus excelsior*) stands the ash dieback (*Chalara fraxinea*) was observed at a larger scale.

In conifers of the older age category (trees 60 years and older), there were no great changes in total defoliation development compared to the preceding year. Defoliation moderately increased only in pine (*Pinus sylvestris*), percent defoliation in class 3 rose from 13.3% in 2017 to 17.6% in 2018 at a parallel decrease in this percentage in class 1 and 2. Similarly, there was a moderate increase in defoliation in larch (*Larix decidua*) in which percent defoliation in class 2 rose from 71.8% in 2017 to 79.5% in 2018 at a parallel decrease in this percentage in class 1. In younger conifers no pronounced changes were observed either, only a slight improvement was found in larch where percent defoliation in class 0 increased from 13.2% in 2017 to 20.6% in 2018 at a parallel decrease in this percentage in class 1 and 2, and also in fir (*Abies alba*) where percent defoliation in class 1 rose from 57.2% in 2017 to 65.6% in 2018 at a parallel decrease in this percentage in class 2. In broadleaves of both age categories a very slight worsening was revealed when percent defoliation in class 2 increased at a decrease in percent defoliation in class 1. Much worse results were obtained in older oak (*Quercus* sp.) stands where percent defoliation in class 2 rose from 61.2% in 2017 to 75.5% in 2018 and in class 3 from 1.1% in 2017 to 4.5% in 2018 at a decrease in this percentage in class 1. In older stands of beech (*Fagus silvatica*) the results were slightly worse as percent defoliation in class 0 decreased from 34.6% in 2017 to 29.9% in 2018 at an increase in this percentage in classes 1 and 2. On the other hand, in the group of other broadleaves a moderate improvement was observed when percent defoliation in class 2 decreased from 20.9% in 2017 to 10.8% in 2018 at an increase in this percentage in class 0 and 1.

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

See our national annual reporting on forest condition (in Czech and English) which includes ICP Forest data on http://www.vulhm.cz/en/msl_download

Outlook

The National Forest Centre (NFC) prepares the annual report Forest Condition Monitoring in the Czech Republic for 2018. This yearbook will summarize the hitherto results of the ICP Forests programme.

Denmark

National Focal Centre

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

Main activities/developments

Participation in:

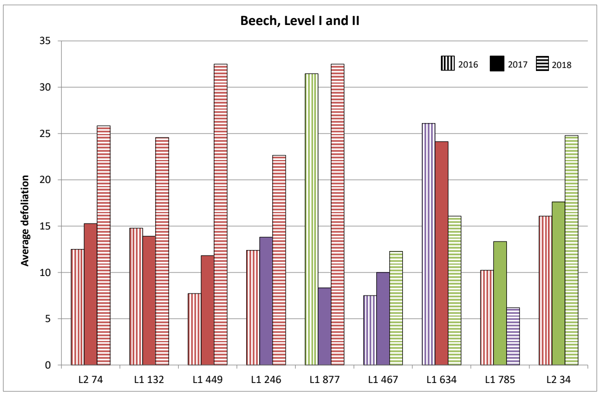
- 7th Scientific Conference and 34th Task Force meeting of ICP Forests (Riga; Latvia)
- 2018 Joint Expert Panel Meeting (Zvolen, Slovakia)
- Forest monitoring (Level II, Level I and NFI plots)

Major results/highlights

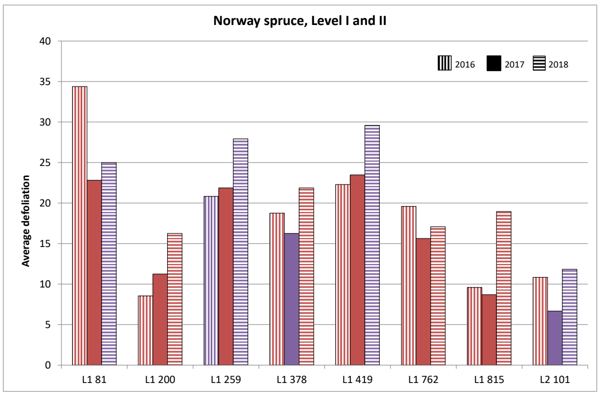
The national crown condition survey showed increased defoliation for most species, mainly due to the extremely warm and dry summer in 2018. Most of the growth season (April-July) had very low precipitation, and the months June-July were very hot in Denmark, similar to the rest of Europe. This caused higher defoliation of particularly beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) compared to the previous years.

Shedding of older needles in spruce continued during autumn and winter and is expected to become visible as increased defoliation in 2019. Newly planted forest cultures had high mortality, but older stands fared better due to high groundwater reserves from the wet autumn and winter of 2017. Long-term impact on growth and health of stressed stands may occur. Several national projects have been initiated to study effects of the 2018 drought.

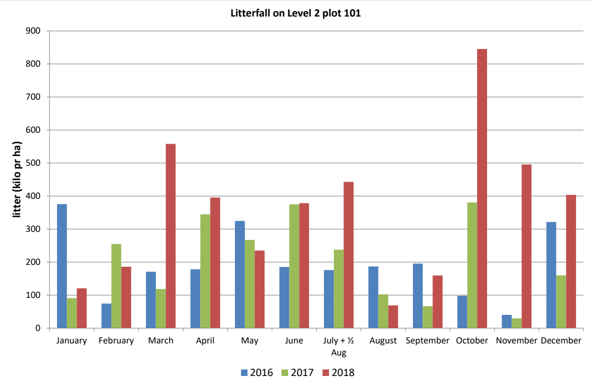
The soils in the 25 Level I sites in Denmark have been resampled in 2018 in connection with a large national repeated soil inventory of a national inventory grid (130 forest plots) that includes the Level I sites. Soils are being analysed only for C and N stocks, but are archived for further analyses should funding be available in the future.



Comparison of average defoliation in the last three years on seven Danish Level I and two Level II plots. Red colour means the assessment took place in August-September, purple is for June-July assessments, and green means a May assessment. For the four plots where assessments took place in June-September all three years, defoliation was significantly higher in 2018 than previous years. The Level I plot 634 is a stand which suffers from fluctuating water levels on a clay soil, and the trees generally have defoliation levels around 20-25%. In 2018, the effect of the drought is not yet visible when the trees were assessed by the end of May.



Comparison of average defoliation in the last three years on seven Danish Level I plots and one Level II plot. Red colour means the asessment took place in August-October, and purple is for June-July assessments. 2017 was a year with high amounts of precipitation. It is expected that defoliation will increase in 2019, as needle shedding continued throughout the autumn on the intensive plot 101.



The amount of litter in litter traps at the Norway spruce intensive monitoring plot in 2016-2018. For July 2018 the litter was collected on August 15, which is why the amount is smaller than normal in August. The amount of needle litter in autumn-winter 2018 is 3-4 times higer than previous years.

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

Nord-Larsen T, Johannsen VK, Riis-Nielsen T, Thomsen IM, Bentsen NS, Gundersen P, Jørgensen BB (2018) Skove og plantager 2017: [Forest statistics 2017.] In Danish with English summary and table/figure tekst. Department of Geosciences and Natural Resource Management, University of Copenhagen. https://static-curis.ku.dk/portal/files/212304755/SP2017_web.pdf

Thomsen IM, Jørgensen BB, Callesen I, Vesterdal L, Ravn HP, Hansen JK, Kjær ED, Nord-Larsen T, Larsen KS, Johannsen VK, Ibrom A (2019) Vurdering af 2018-tørkens indflydelse på skovbruget – [Estimation of the effect of the 2018 drought on Danish Forestry] IGN Notat, Institut for Geovidenskab og Naturforvaltning, Københavns Universitet. 18 p.

Thomsen IM, Jørgensen BB, Callesen I, Ravn HP (2019) 2018-tørkens indflydelse på skovbruget. 1. Sundhed og overlevelse. [The impact of 2018 drought on forests. 1. Health and survival]. Skoven 31(3): 106-111

Callesen I, Jørgensen BB, Vesterdal L., Larsen KS, Hansen JK, Thomsen IM, Ibrom A, Pilegaard K (2019) 2018-tørkens indflydelse på skovbruget. 2. Tilvækst og jordvand. [The impact of 2018 drought on forests. 1. Growth and soil water]. Skoven 31(3): 112-116

Outlook

- Analysis of level I soil C and N data will be carried out during the next year.
- Use of Level I and II sites for further monitoring of 2018 drought effects

Estonia

National Focal Centre

Endla Asi, Estonian Environment Agency

Main activities/developments

The Level I forest monitoring network was used to assess the health status of 2 404 trees. 1 483 Scots pines (*Pinus sylvestris*), 579 Norway spruces (*Picea abies*) and 342 deciduous species, mainly silver birches (*Betula pendula*) were assessed. The observation period lasted from July 10 to November 5, 2018.

On Level II the following forest monitoring activities were carried out in 2018: (1) chemical analyses of the deposition water collected throughout the year on 6 sample plots; (2) chemical analyses of soil solution collected during 7 months of the year (from April to October) on 5 sample plots; (3) from one plot analyses of the litterfall were collected according to ICP Forests requirements; (4) foliar samples collected in December 2017 were analysed on all sample plots.

Major results/highlights

Level I

The total share of not defoliated trees, 49.6%, was 6.6% lower than in 2017. The share of not defoliated conifers, 47.2%, was lower than the share of not defoliated broadleaves, 64.0%, in 2018.

Share of trees in classes 2 to 4, moderately defoliated to dead, was 8.2% in 2018 and 5.2% in 2017. Share of conifers and broadleaves in defoliation classes 2 to 4 was 8.9% and 3.8% accordingly.

The share of not defoliated pines (defoliation class 0) was 45.9% in 2018, 8.9% lower than in 2017. The share of pines in classes 2 to 4, moderately defoliated to dead, was 7.4%, higher than in 2017. The defoliation of Scots pine increased in 2018, mainly caused by drought and insect damage.

However, long-term trend of Scots pine defoliation since 2009 has been improved. In 2009, the share of not defoliated pine trees was 38% compared to 45.9% in 2018.

A long-term increase of defoliation of Norway spruce may be observed. The share of not defoliated trees (defoliation class 0) was 63.7% in 2010 and 50.8% in 2018. The share of not defoliated trees was higher, 74.0%, in younger stands with the age up to 60 years and 33.1% in older stands.

Compared to several last years there has been a significant decrease in the condition of broadleaves during 2015 and 2016. The defoliation of broadleaves improved in 2018. Compared to 2017 the defoliation of silver birches has improved 4.8% in 2018.

The share of not defoliated silver birches was 59.6% in 2018 and 54.8% in 2017.

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. All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage.

In 2018, 4.9% of the trees observed had some insect damages, 16.9% had symptoms of fungi (mainly Scots pines). Overall 36% 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 17% of the observed pine trees in 2018, compared to 16% in 2017. Norway spruces mostly suffered due to root rot (pathogen *Heterobasidion parviporum*) – characteristic symptoms of the disease were observed on 4.1% of sample trees.

No substantial storm damages and forest fires occurred in 2018.

Level II

The annual average pH of the precipitation was varying mainly between 5 and 6. Long-term observations show some slight decrease of pH since 2012. The content of analysed chemical elements and compounds in precipitation water was low. Generally the amount of precipitation in 2018 was remarkably lower than in 2017.

The pH of the soil solution varied between 3.9 and 6.5 throughout the observation period. The content (concentration) of the nutrition elements and chemical compounds dissolved in the soil water of pine stands was in most cases also below the level of 2.5 mg·l^{-1}. In 2018, similar to the past years, the content of Ca^{2+}, K^+ and Cl^- in soil solution was considerably higher than the mentioned level in all spruce sample plots. The concentration of Mg^{2+}, Na^+ and SO_4-S in spruce stand at Karepa was essentially higher than the level of 2.5 mg·l^{-1}.

The results of litterfall collected in 2017 did not show any significant trends of diferent elements. Rather higher values could be detected in different fractions of litterfall.

The chemical analyses of foliage, gathered in 2017, indicated that content of the nutrition elements was similar to the previous observation period 2015/2016. Content of the nutrients was on optimal level or close to it on all Level II sample plots.

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

Annual publications/reports:

Yearbook Forest, Chapter 5 – Condition of forest, The Estonian Environment Agency, Tallinn 2018

FOREST MONITORING, Report of the survey 2018. Vladislav Apuhtin, Tiiu Timmusk, The Estonian Environment Agency, Tartu 2018

Outlook

The forest monitoring activity in Estonia will continue for both levels (Level I and Level II) and no significant changes are planned for 2019.

Finland

National Focal Centre

Päivi Merilä, Natural Resources Institute Finland (Luke)

Main activities/developments

In 2018, eight Level II plots were monitored for atmospheric deposition, soil solution chemistry, litterfall, and meteorology, as well as for crown condition. In addition, tree increment was monitored using girth bands by manual recordings (eight plots) and by electronic devices (two plots). The monitoring data for the year 2016 was submitted to the ICP Forests database.

ICP Forests Expert Panel chair Pasi Rautio (EP Foliage and Litterfall), co-chair Liisa Ukonmaanaho (EP Foliage and Litterfall), and co-chair Tiina M. Nieminen (EP Soil and Soil Solution) continued in their posts and contributed to the work of Programme Coordinating Group of ICP Forests.

Major results/highlights

Salemaa et al. (2019) investigated the biological fixation of atmospheric nitrogen (BNF) by moss-associated cyanobacteria on 12 Level II plots in Finland. In moss samples taken along the north–south gradient with an increasing N bulk deposition from 0.8 to 4.4 kg ha^{-1} year^{-1}, they found a clear decrease in BNF on both feather mosses and *Dicranum* group. BNF turned off at N deposition of 3–4 kg ha^{-1} year^{-1}. The results thus suggest that even relatively low N deposition suppresses BNF in bryophyte-associated cyanobacteria.

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

Holmberg M, Aherne J, Austnes K, Beloica J, De Marco A, Dirnbock T, Fornasier MF, Goergen K, Futter M, Lindroos AJ, Kram P, Neirynck J, Nieminen TM, Pecka T, Posch M, Proll G, Rowe EC, Scheuschner T, Schlutow A, Valinia S, Forsius M (2018) Modelling study of soil C, N and pH response to air pollution and climate change using European LTER site observations. Science of the Total Environment 640:387-399. doi: 10.1016/j.scitotenv.2018.05.299

Salemaa M, Lindroos A-J, Merilä P, Mäkipää R, Smolander A (2019) N-2 fixation associated with the bryophyte layer is suppressed by low levels of nitrogen deposition in boreal forests. Science of the Total Environment 653:995–1004. doi: 10.1016/j.scitotenv.2018.10.364

Vuorenmaa J, Augustaitis A, Beudert B, Bochenek W, Clarke N, de Wit HA, Dirnbock T, Frey J, Hakola H, Kleemola, S, Kobler J, Kram P, Lindroos AJ, Lundin L, Lofgren S, Marchettom A, Pecka T, Schulte-Bisping H, Skotak K, Srybny A, Szpikowski J, Ukonmaanaho L, Vana M, Åkerblom S, Forsius M (2018) Long-term changes (1990–2015) in the atmospheric deposition and runoff water chemistry of sulphate, inorganic nitrogen and acidity for forested catchments in Europe in relation to changes in emissions and hydrometeorological conditions. Science of the Total Environment 625:1129-1145. doi: 10.1016/j.scitotenv.2017.12.245

Outlook

In 2018, three of the Finnish Level II monitoring plots (Evo nr. 19, Lieksa nr. 20, and Pallasjärvi nr. 3) were selected to the network of sites for monitoring the negative impacts of air pollution upon ecosystems under the National Emissions Ceilings (NEC) Directive (2016/2284/EU). The plots also belong to the ICP IM programme. These plots will thus form the basis for collecting and reporting the information concerning forest ecosystems required under the NEC Directive.

On the other hand, five Level II plots (Tammela nrs. 12 and 13, Juupajoki nrs. 10 and 11, and Pallasjärvi nr.3) have been earlier included in the Finnish National Research Infrastructure (NRI) facilities, which have joined the European eLTER RI (Integrated European Long-Term Ecosystem, Critical Zone & Socio-Ecological Research Infrastructure) facilities. In 2018, eLTER RI was accepted onto the EU's 2018 ESFRI (European Strategy Forum on Research Infrastructures) roadmap, paving the way for the further development of eLTER RI and its NRIs, including these Finnish Level II plots.

In addition to the UNECE ICP Forests programme, these two EU related initiatives will strengthen the prospects of the Level II programme in Finland.

France

National Focal Centre

Level I: Fabien Caroulle, Ministère de l'Agriculture, de l'Agro-alimentaire et de la Forêt
Level II: Manuel Nicolas, Office National des Forêts

Main activities/developments

Level I

A national network on soil quality named "RMQS" (Soil Quality Measurement Network) is cast on the French ICP Forests network. Each year, some plots are monitored to asses soil quality. Furthermore, this network also exists on agricultural soils, in order to achieve a complete overview of non artificial soils in the country.

Level II

Monitoring activities were continued on the 102 plots of the Frenche Level II network (RENECOFOR). In detail, tree assessments (phenology, health, annual growth) were performed on all of these plots, while atmospheric deposition, meteo, soil solution and litterfall have been monitored only on a subset of plots. In the 14 plots where throughfall deposition is monitored, the old gutters (most of them more than 25 year old) were replaced by some new ones that were designed with the same sampling area and checked for no contamination of deposited solution (tests were performed before the gutters were installed in the plots).

Major results/highlights

Level I

In 2018, the forest damage monitoring in the French part of the systematic European network comprised 10 707 trees on 533 plots.

Summer and autumn were in 2018 particularly dry and sunny, and especially hot during August. Due to this drought, and the one of the former year, all species, and especially broadleaved species, show an increase in their mean defoliation. Evergreen oak (*Quercus ilex*) and chestnut (*Castanea sativa*) are the main species that suffer the most of foliage loss.

Damage was reported on about a half of the sampled trees, mainly on broadleaved species. The most important causes of damage were Chalara ash dieback (*Chalara fraxinea*) on ashes (*Fraxinus* spp); mistletoe (*Viscum album*) on *Pinus sylvestris;* chestnut canker (*Cryphonectria parasitica*) and the oak buprestid (*Coroebus florentinus*) on oaks (*Quercus* spp.).

Level II

The Level II data are extracted for free from the RENECOFOR's database on the request of researchers. They have been used for various purposes, as depicted by the PhD theses and articles published in 2018 in peer-reviewed journals (cf. list below).

The litterfall data collected on the 102 French Level II plots from 1994 to 2007 have already proved to be of high interest to study tree fruit production in response to climate, as they were used for this purpose in several articles published since 2016. In 2018, they were also useful in combination with foliar analyses to study nutrient remobilization. This process enables trees to store nutrients that will be useful at the beginning of the next growing season, and it contributes to forest adaptation to nutrient-poor conditions. But the ecological factors that regulate it still need to be better understood. Thanks to the large environmental gradients covered by the 102 plots, Achat et al. (2018) were able to evaluate the influence of soil and climate condition and of leaf life span on the nutrient remobilization rate from tree leaves. Overall, leaf life span and nutrient availability in soil are the two most important factors. Total amounts or availability of nutrients in soils were negatively correlated with nutrient remobilization: the larger the soil nutrient pool, the lower the remobilization. This was the case for N and P, as assessed in some previous studies, but also – what was newly evidenced – for S and base cations. This general ecological pattern is modulated by ecophysiological constraints of plants, mainly leaf life span or the capability of plants to move Ca through the phloem sap.

While air pollution and climate change have been considered as some main environmental threats to forest ecosystems, some biological factors may also have some strong impacts in addition, like the density of wild ungulate populations (which increased in France for the last decades). Boulanger et al. (2018) evaluated the impact of these populations by comparing the temporal variation of the ground vegetation composition inside and outside the fenced central part of RENECOFOR plots. Differences were already significant after 10 years. Outside, forest ungulates maintained higher species richness in the herbaceous layer (+15%), while the shrub layer was 17% less rich, and the plant communities became more light-demanding. Inside, shrub cover increased, often to the benefit of bramble (*Rubus fruticosus* agg.). However ungulates tend to favour ruderal, hemerobic, epizoochorous and non-forest species. To sum up, they increase plant species richness in forest but to the benefit of non-forest species.

In addition to the data, the samples collected for forest monitoring can also be used by researchers for further measurements. For example, Soucémarianadin et al. (2018a, 2018b) used RENECOFOR's archived soil samples to compare several methods for characterizing soil organic carbon stability, and to evaluate the influence of environmental factors (soil, climate, and vegetation type) on it. As another example, in her PhD thesis, Roulier (2018) analysed deposition, litter and soil samples in order to explore the largely unknown iodine cycle in terrestrial ecosystems and so to improve risk assessments, since iodine can be involved in the dispersal of radioactivity into the environment in case of nuclear event. These examples illustrate the usefulness of the Level II network also to address issues for which it was not initially designed.

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

In the following only national publications and publications reviewed in the above text are listed. For international peer-reviewed articles, please refer to the Overview of ICP Forests-related publications (January – December 2018) in this report.

Goudet M (2018) Results on French forest damages assessment network. https://agriculture.gouv.fr/telecharger/90056?token=01a8876ef1721d701980cb9da6c0d15d (in French)

Achat DL, Pousse N, Nicolas M, Augusto L (2018) Nutrient remobilization in tree foliage as affected by soil nutrients and leaf life span. Ecological Monographs, 88(3):408-428, DOI: 10.1002/ecm.1300

Boulanger V, Dupouey JL, Archaux F, Badeau V, Balyzinger C, Chevalier R, Corcket E, Dumas Y, Forgeard F, Marell A, Montpied P, Paillet Y, Picard JF, Saïd S, Ulrich E (2018) Ungulates increase forest plant species richness to the benefit of non-forest specialists. Global Change Biology, 24(2)e485-e495, DOI: 10.1111/gcb.13899

Roulier M (2018) Cycle biogéochimique de l'iode en écosystèmes forestiers. Thèse de doctorat. Université de Pau et des Pays de l'Adour. 234 p.

Soucémarianadin L., Cécillon L., Chenu C., Baudin F., Nicolas M., Girardin C., Barré P., 2018. Is Rock-Eval 6 thermal analysis a good indicator of soil organic carbon lability? – A method-comparison study in forest soils. Soil Biology and Biochemistry, 117:108-116, DOI: 10.1016/j.soilbio.2017.10.025

Soucémarianadin L., Cécillon L., Guenet B., Chenu C., Baudin F., Nicolas M., Girardin C., Barré P., 2018. Environmental factors controlling soil organic carbon stability in French forest soils. Plant and Soil, 426(1-2):267-286, DOI: 10.1007/s11104-018-3613-x

Outlook

The French Level II network (RENECOFOR) will reach its initially defined 30-yr horizon in 2022. In October 2017, the conference organized for its 25th anniversary successfully drew the attention on its usefulness and on the need for longer-term forest monitoring. Since then workshops have been organized with its scientific board to elaborate future scenarios to be submitted to national funders for negotiations planned from autumn 2019. Such scenarios must be scientifically sound, policy-relevant, but also feasible in the long run. For example, while all plots were initially selected under adult forest stands, many of them will enter a regeneration stage within the next few decades: Should we move these plots or keep monitoring whatever will grow up next at the same locations? This is a matter of monitoring targets and strategy, and some clear orientations need to be chosen to keep this network consistent, relevant and powerful. If possible it must also adapt to better respond to concerns about climate change impacts and biodiversity dynamics.

Germany

National Focal Centre

Sigrid Strich, Federal Ministry of Food and Agriculture
Scientific support: Thünen Institute of Forest Ecosystems

Main activities/developments

Germany continued its assessment at Level I and II. The 2018 crown condition survey took place on 410 Level I plots with a total number of 9857 sample trees. Level II data have been submitted for 87 plots.

Major results/highlights

Crown condition Level I

In summer 2018, defoliation on 29% of the forest area was classified as moderate to severe (defoliation classes 2 to 4; this means defoliation > 25%). This is an increase by 6 percentage points compared to 2017. Both in 2017 and 2018, 43% of the investigated forest area was in the warning stage (slightly defoliated). 28% (2017: 34%) showed no defoliation. Mean crown defoliation increased from 19.7% to 22.0%. Only in 2004 mean crown defoliation was higher and reached 22.8%.

Picea abies: The percentage of defoliation classes 2 to 4 increased from 25% to 30%. Forty per cent (2017: 39%) of the trees were in the warning stage. The share of trees without defoliation was 30% (2017: 36%). Mean crown defoliation increased from 19.7% to 21.5%.

Pinus sylvestris: The share of defoliation classes 2 to 4 remained nearly unchanged, 15% compared to 14% in 2017. The share of the warning stage increased from 49% to 54%. 31% (2017: 37%) showed no defoliation. Mean crown defoliation increased from 17.4% to 18.3%.

Fagus sylvatica: The share of trees in the defoliation classes 2 to 4 reached 39%. This is a deterioration compared to 2017 (31% of moderately to severely defoliated trees). 42% (2017: 44%) were in the warning stage. The share showing no defoliation was 19% (2017: 25%). Mean crown defoliation increased from 22.5% to 25.1%.

Quercus petraea and *Q. robur*: The share of moderately to severely defoliated trees increased from 32% to 42%. The share of trees in the warning stage decreased from 43% to 38%. The share without defoliation decreased from 25% to 20%. Mean crown defoliation increased from 22.9% to 25.7%.

Intense fruiting was observed on almost all tree species. The vegetation period 2018 was characterized by an intense and long lasting drought period and a severe outbreak of *Ips typographus*.

Intensive forest monitoring (Level II)

The focus of national analyses within the intensive forest monitoring was within the surveys dendroecology, foliar, and deposition. For deposition the main effort was the comparison of different canopy budget models (CBMs) to estimate the total nitrogen (N) deposition to forests. Consensus has been reached among the German ICP Forests partners on how to report national estimates of total N deposition to forests. Accordingly, a lower boundary of the deposition rate should be reported as the sum of inorganic N deposition below canopy (throughfall + stemflow) and the deposition rate of organic N in the bulk open field measurements. An upper boundary should be reported derived from the higher of the two estimates of the total N deposition according to the CBMs after Ulrich (1994) and De Vries et al. (2001), respectively, plus the deposition rate of organic N in the bulk open field measurements. The consensus includes further specifications about the corresponding CBMs and will be implemented and published in form of an R script. We acknowledge that the deposition rate of total nitrogen can exceed the upper reporting boundary, for example due to the stomatal uptake of gaseous N compounds, due to shortcomings of the CBMs in representing other canopy uptake processes as well as due to the conversion of inorganic to organic N in the canopy.

Data on tree nutrition for Level II plots in Germany currently cover the period 1990 to 2017. The four main tree species differ in their nutritional status: In the period since 2010, N concentrations in leaves of European beech were high at about 61% of Level II plots, whereas in needles of Norway spruce, N concentrations were low at about 59% of Level II plots. For temperate oak and Scots pine forests, most plots are within adequate to optimum ranges. P concentrations in leaves and needles of all four tree species are below critical limits at a large number of Level II plots. 61% of European beech and 76% of Norway spruce plots show P deficiency based on foliar analysis.

Interrelations between tree nutrition and tree growth were analysed for European beech and Norway spruce for the period between 1990 and 2004. Foliar P significantly affects mean basal area increment width in European beech, although the effect is small compared to temperature (temporal scale) or soil conditions (spatial scale). In Norway spruce, the links between foliar P and growth depend on the observed year. Within the studied time period, explained deviance of basal area increment width between plots by foliar P was highest in 1997, a positive pointer year for Norway spruce.

From dendroecological analysis we further find clear responses to past extreme events. However, the growth in the years after extreme events shows for the four main tree species in Germany that they do recover - albeit taking up to three years - after the event.

Ongoing projects

A project of the Thünen Institute and the Northwest German Forest Research Institute, funded by the German Environment Agency, aims to develop cost effective (bulk-) samplers for monitoring the deposition of mercury on Level II plots. Additionally, the interference of leaves, fruits, branches, insects or bird droppings with the samples will be studied in order to estimate the uncertainty of deposition rates. First observations with 9 samplers in a beech forest and 3 samplers in the open field show promising results as to feasibility and reliability of the developed monitoring method. The open field input is comparable to results of 5 monitoring stations of the German Environmental Agency. Throughfall input of Hg into the beech forest is about twice as high as in the open field. First results have been presented at the Combined Expert Panel Meeting in Brussels.

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

Raspe S, Dietrich H-P, Köhler D, Schubert A, Stiegler J (2018) Stickstoff im Überfluss - Waldböden in Bayern reichern Stickstoff weiter an. LWF aktuell.

Ziche D, Sanders TG, Beck W, Bolte A, Gutsch M, Helle G, Natkhin M (2018) Dendrochronologische Analyse der Anpassungsfähigkeit von Kiefer und Eiche an sich ändernde Umweltbedingungen. In: Ammer C, Bredemeier M, Arnim G von (eds) FowiTa: Forstwissenschaftliche Tagung 2018 Göttingen ; Programm & Abstracts ; 24. bis 26. September 2018. Göttingen: Univ Göttingen, Fakultät für Forstwissenschaften und Waldökologie, 388 p

Schad T, Sanders TG, Werner W, Eghdami H (2018) Erarbeitung von Vorschlägen für ein repräsentatives Messnetz zur Überwachung der Wirkungen bodennahen Ozons in Umsetzung der Richtlinie (EU) 2016/2284, Artikel 9 und Anhang V: Abschlussbericht. Dessau: Umweltbundesamt, 141 p, Texte UBA 114

Fore more publications, please refer to:

https://blumwald.thuenen.de/level-ii/literatur/publikationen-der-bundeslaender/

https://blumwald.thuenen.de/level-ii/literatur/nationale-veroeffentlichungen/

Outlook

- Future developments of the ICP Forests infrastructure: creation of a national data base and inclusion of a lysimeter site in the network with all but the chemical analysis already up to standard;
- Planned research projects: use of unmanned aerial vehicles (drones) to assess phenology, tree height and further crown parameters;
- In 2019 Germany will organize the crown condition field and photo ICCs.

Greece

National Focal Centre

Dr Panagiotis Michopoulos, Hellenic Agricultural Organization – DEMETER, Institute of Mediterranean Forest Ecosystems (www.fria.gr)

Main activities/developments and major results/highlights

Level I plots

Crown condition assessment

For the assessment of the crown condition, data was collected from 40 plots representing a 40% percentage of the total number of the Level I plots in our country. More specifically, in 2018 the number of trees counted was 936, whereas in 2017 the number of trees was 855. From the 936 trees, 317 were conifers and 619 broadleaves.

The following table shows the results of the crown assessment for all tree species.

Crown assessment (Level I plots) (in %)

	All tree species	Conifer species	Broadleaf species
No defoliation	57.2	35.0	68.5
Slight defoliation	24.6	37.4	17.0
Moderate defoliation	15.0	23.7	10.5
Severe defoliation	1.6	1.0	1.9
Dead trees	1.3	0.0	1.9

It was found that 81.7% of all trees belonged to the classes "No defoliation" and "Slight defoliation". The corresponding values were 72.5% and 85.4% for conifers and broadleaves, respectively. The major damage causes for needle loss in conifers were insects, European mistletoe and abiotic factors. With regard to broadleaves, the most important agents for the leaf loss were insect attack and abiotic factors.

Level II plots

In Greece, there are four Level II plots. Plot 1 having an evergreen broadleaved vegetation (maquis, with mainly *Q.ilex*), plot 2 with deciduous oak (*Q. frainetto*), plot 3 with beech (*F.sylvatica*) and plot 4 with Bulgarian fir (*A. borisii-regis*). Full scale activities take place in plots 1 and 4 and from 2017 also in plot 2.

From the meteorological data assessment it was found that the average monthly air temperature values were particularly low in all plots in January 2017. The rest of the year, values ranged close to the average ones recorded at the stations during all their years of operation.

With regard to the rainfall in all plots, the average annual amount for 2017 was close to the average annual value foe the fir and maquis plots (calculated in the last 45 years) while for the beech plot the amount of precipitation was 23% higher than the average one.

Crown condition assessment (Level II plots)

The crown assessment in 2017 in the four Level II plots comprised a total number of 168 trees (35 conifers and 133 broadleaves). The results showed an improvement in tree health in comparison with the results of the previous years (see the following table).

Crown assessment (Level II plots) (in %)

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
	2016	29.4	47.1	17.6	5.9	0.0
	2017	31.4	54.3	8.6	5.7	0.0
Broadleaves	**2014**	48.5	41.2	7.4	2.2	0.7
	2015	47.1	35.3	10.3	4.4	2.9
	2016	43.2	41.7	9.8	5.3	0.0
	2017	49.6	33.8	10.5	5.3	0.8

Deposition

The following table shows the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak and fir plots in 2017. The amount of rain for 2017 was higher in the fir plot and as a result, this fact contributed to the fluxes magnitude. However, the dry deposition in the oak plot was higher than the other plots as can be seen from the throughfall fluxes of SO_4^{2-} -S and NO_3^- -N.

Fluxes (kg ha^{-1} yr^{-1}) of major ions in deposition (throughfall (T) and bulk (B)) in three forest plots

Plots	Dep.	Ca	Mg	K	$SO4^{2-}$-S	NH_4^+-N	NO_3^--N	mm
Maquis	T	11.3	3.49	44.1	16.4	0.52	1.96	781
	B	10.3	2.16	5.6	9.4	0.76	1.87	1090
Oak	T	18.2	4.16	47.0	22.5	3.44	9.53	1311
	B	9.1	1.91	5.4	17.7	2.94	3.00	1726
Fir	T	20.1	6.13	61.9	19.9	2.62	2.75	1366
	B	14.1	3.00	11.6	13.1	4.53	5.15	1530

Litterfall

The beech plot had the highest fluxes of all major nutrients in foliar litterfall in 2017 (s.b.). For the non-foliar litter the fir plot had by far the highest amounts of all nutrients with the exception of K, which was high in the oak plot. It is notable that the N content in the non-foliar litter in the fir plot was half the amount of N in the foliar litter.

Fluxes (kg ha^{-1} yr^{-1}) of major nutrients in litterfall in four forest plots in 2017

Foliar	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	56.0	6.09	14.6	4.30	49.3	2.03
Oak	75.5	11.70	17.6	6.24	48.4	3.39
Beech	110.0	14.00	14.0	8.84	85.5	3.60
Fir	85.2	5.86	12.2	4.86	50.2	2.73
Non Foliar	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	5.8	1.05	2.68	0.61	6.2	0.41
Oak	13.3	1.89	10.60	1.12	10.5	1.19
Beech	13.6	0.79	1.20	0.47	5.2	0.36
Fir	23.1	2.89	5.47	2.78	24.8	2.06

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

- Michopoulos P, Bourletsikas A, Kaoukis K, Daskalakou E, Karetsos G, Kostakis M, Thomaidis NS, Pasias IN, Kaberi H, Iliakis S (2018) The distribution and variability of heavy metals in a mountainous fir forest ecosystem in two hydrological years. Global Nest 20: 188-197
- Neumann M, Ukonmaanaho L, Johnson J, Benham S, Vesterdal L, Novotný R, Verstraeten A, Lundin L, Thimonier A, Michopoulos P, Hasenauer H (2018) Quantifying Carbon and Nutrient Input From Litterfall in European Forests Using Field Observations and

Modeling. Glob Biogeochem Cycles 32:784–798. doi: 10.1029/2017GB005825

- Koulelis P, Daskalakou E, Michopoulos P (2018) Testing non-linear height-diameter functions for three native trees of Greece on ICP Forests Level II plots. Austrian J For Sci 4:297-314

Hungary

National Focal Centre

László Kolozs, Forestry Directorate, National Food Chain Safety Office (NÉBIH)

Main activities/developments

In 2018, the large-scale health condition monitoring (Level I) was coordinated and carried out by the experts of the Forestry Directorate. 78 permanent plots with a total of 1869 sample trees were included in the field assessment. The survey was carried out between 15th July and 15th August. The major results of 2018 are based on these data of this assessment.

Major results/highlights

Level I

In this year only 26.5% of the trees were without visible defoliation, which shows a little decrease in comparison with 2017 (29.9%). The percentage of the slightly defoliated trees was 26.2%, and the percentage of all trees within ICP defoliation classes 2-4 (moderately damaged, severely damaged and dead) was 47.3%. The rate of the dead trees was 2% but only 0.4% of them died in the surveyed year. Dead trees remain in the sample as long as they are standing. The mean defoliation for all species was 30.4% and had increased compared to the year of 2017 (28.8%).

Some negative alteration was observed in respect of the defoliation rates of most of the main species in 2018. *Pinus nigra* (black pine) and *Quercus robur* (pedunculate oak) were the two most defoliated tree species: The percentage of the sample trees in the healty category (defoliation class 1) was under 10% in both groups. The *Carpinus betulus* (common hornbeam), the *other hardwood species* and *Fagus sylvatica* (beech) were the least defoliated tree species in 2018.

Although the discoloration slightly increased during the previous two years but it is still under the normal level, 85.8% of all sample trees did not show any discoloration in 2018.

In 2018, on 86% of all the trees at least one symptom of damage was found. Insects (25.0%) and fungi (22.6%) were the most frequent damaging agents generally although there are differences in proportions between the affected tree species. The damages caused by insects (mostly defoliators) occurred on *Quercus petraea* (sessile oak), *other oak species* and *Pinus sylvestris* (Scots pine). Fungal damages were observed on *Pinus nigra* in the highest rate (66.7%) and on *Quercus robur*, too, which correlates with the bad condition of these species.

Abiotic damages (16.6%) were the third most frequent damaging agent: Most of the identified symptoms were caused by drought, hot weather, or frost. The frequency of the damages with unknown origins was 15.6%. The rates of the damages caused by other biotic agents (9.1%), human induced (5.5%) and game and wildlife (4.7%) did not change significally compared to the previous years. The signs of fire damage were not a lot observed in the assessed stands (0.9%).

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

"Erdeink egészségi állapota 2018-ban" The annual national report on the health condition of the Hungarian forest which includes ICP Forests plot data is available (in Hungarian) online at http://portal.nebih.gov.hu/-/emmr-kiadvanyok-jelentesek.

Ireland

National Focal Centre

Thomas Cummins, UCD Soil Science, University College Dublin
John Redmond, Forest Service, Department of Agriculture Food and the Marine, Wexford

Main activities/developments

There was no activity under ICP Forests during 2018. Stakeholder discussions on a plot network for monitoring under the NEC Directive using ICP Forests methods were held. Plot locations for Level I and Level II networks were submitted under the NEC Directive by the Department of Communications, Climate Action and Environment.

Major results/highlights

No results are available for 2018 from Ireland.

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

No publications during 2018.

Outlook

- Level I forest health monitoring is expected in 2019, operated by the Forest Service, Department of Agriculture, Food and the Marine. Sampling will take place at 35 forest plots which are located on a 16 × 16 km grid, which is a sub-set of Ireland's National Forest Inventory 2 km sampling frame.

- Level II monitoring of forest plots, using ICP Forests methods, has been proposed by the Department of Communications, Climate Action and Environment to satisfy the requirements of the NEC Directive. It has not yet been established who will co-ordinate and undertake the Level II forest monitoring.

Italy

National Focal Centre

Giancarlo Papitto, Carabinieri Corps – Office for Studies and Projects

Report on 2018 national crown condition survey

The survey of Level I in 2018 took into consideration the condition of the crown of 4890 selected trees in 249 plots on a 16x16 km grid belonging to the ICP Forests network. The results given below relate to the distribution of frequencies of the indicators used, especially transparency - which in our case we use for the indirect assessment of defoliation, and the presence of known causes attributable to both biotic and abiotic agents. For the latter, not so much the indicators we analyzed the frequencies of affected plants, but the comments made as to each plant may have multiple symptoms and more agents.

Defoliation data are reported according to the usual categorical system (class 0:0-10%; class 1: >10-25%; class 2: >25-60%; class 3: >60%; class 4: tree dead): most trees (77.4%) are included in the classes 1 to 4; 38.6% are included in the classes 2 to 4.

By analyzing the sample for groups of species, conifers and broadleaves, it appears that conifers have a lower transparency than deciduous foliage: 43.1% of conifers and 15.3% of broadleaves were in the transparency class 0, while 25.7% of conifers and 43.3% of broadleaves are included in the classes 2 to 4.

For a survey of the frequency distribution of the parameter for transparency, species were divided into two age categories (<60 and >60 years), among the young conifers (<60 years), *Pinus nigra* has 60.0% of trees in the classes 2 to 4, *Picea abies* and *Pinus sylvestris* have respectively 15.2% and 32.6% of trees in the classes 2 to 4.

Among the old conifers (>60 years), the species appearing to be with the worst quality of foliage were *Pinus sylvestris* (29.2%), *Larix decidua* (24.9%) and *Abies alba* (22.3%) of trees in the classes 2 to 4, while *Picea abies* (15.6%) and *Pinus nigra* (22.0%) resulted to be the conifers in better condition.

Among the young broadleaves (<60 years), in *Castanea sativa, Fagus sylvatica* and *Quercus pubescens* 72.9%, 54.2% and 52.6%, respectively, of trees are in the classes 2 to 4, while others like *Quercus cerris* and *Ostrya carpinifoglia* have a frequency between 33.7% and 43.1% in classes 2 to 4.

Among the old broadleaves (>60 years) in the classes 2 to 4, *Castanea sativa* has 76.6%, *Quercus pubescens* 50.4%, *Fagus sylvatica* 31.4% and *Quercus cerris* 30.6%, while *Quercus ilex* (18.9%) has the lowest percentage of trees in the defoliation classes 2 to 4.

Starting from 2005, a new methodology for a deeper assessment of damage factors (biotic and abiotic) was introduced. The main results are summarized below.

Most of the observed symptoms were attributed to insects (18.4%), subdivided into defoliators (15.2%), galls (1.2%). Following were symptoms attributed to fungi (4.5%), the most significant were attributable to "dieback and canker fungi" (2.6%). Of those assigned to abiotic agents, the most significant were attributable to frost (2.1%) and drought (1.2%).

Latvia

National Focal Centre

Uldis Zvirbulis; Andis Lazdins and Ainars Lupikis (Level II), Latvian State Forest Research Institute Silava

Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2018 in Latvia was carried out on 115 Level I NFI plots. The major results of 2018 are based on data from this dataset.

Major results/highlights

In total, defoliation of 1735 trees was assessed, of which 76% were conifers and 24% broadleaves. Of all tree species, 12.8% were not defoliated, 82.2% were slightly defoliated and 5.0% moderately defoliated to dead. Compared to 2017, the proportion of not defoliated trees has increased by 1.4%, the proportion of slightly defoliated has decreased by 1.1%, but the proportion of moderately defoliated to dead trees has decreased by 0.2%. In 2018, the proportion of not defoliated conifers was by 8.7% higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was by 3.8% higher than that of slightly defoliated conifers. The proportion of trees in defoliation classes 2-4 for broadleaves was 4.9% higher than for conifers.

Mean defoliation of *Pinus sylvestris* was 19.5% (19.9% in 2017). The share of moderately damaged to dead trees constituted 4.3% (4.8% in 2017). Mean defoliation of *Picea abies* was 17.3% (19.1% in 2017). The share of moderately damaged to dead trees for spruce constituted 2.9% (6.0% in 2017). The mean defoliation level of *Betula* spp. was 20.8% (20.7% in 2017). The share of trees in defoliation classes 2-4 was 8.8% (compared to 5.2% in 2017).

Visible damage symptoms were observed to a smaller extent than in the previous year – 17.3% of the assessed trees (17.8% of the assessed trees in 2017). Most frequently recorded damages were still caused by direct action of men (35.2%; 34.5% in 2017), animals (26.2%; 24.2% in 2017), fungi (11.1%; 11.3% in 2017), abiotic factors (13.1%; 12.3% in 2017) and insects (11.1%; 11.0% in 2017) and unknown cause – for 3.4% (6.8% in 2017). The distribution of damage causes was similar as in last year. Proportion of insect damages has stabilized including proportion of damages by European pine sawfly *Neodiprion sertifer*. The greatest share of trees with damage symptoms was recorded for *Picea abies* (25.6%), *Pinus sylvestris (15.3%)* and the smallest for *Betula* spp. (12.4%).

Level II plots observed higher rates of needle damages done by insects.

Outlook

Currently, Latvia has 115 Level I plots and 3 sample plots for Level II monitoring and it is planned to maintain those sample plots also in future and continue measurements on all of the plots. We are slowly changing the old and damaged equipment with a new one. There are no plans for significant changes or improvements in the next year.

Lithuania

National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

Main activities/developments

Level I

In 2018, the forest condition survey was carried out on 1068 sample plots from which 81 plots were on the transnational Level I grid and 987 plots on the National Forest Inventory grid. In total 6605 sample trees representing 17 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*.

Level II

In 2018 Intensive monitoring activities have been carried out at 9 Intensive Monitoring Plots according to ICP Forests requirements: sampling of bulk and throughfall precipitation for chemical analyses, sampling of soil solution water and litterfall sampling (3 plots), the crown condition and ozone injury assessment (9 plots). The crown condition assessment in 2018 in the nine Level II plots took place on a total number of 507 model trees.

Major results/highlights

During one year the mean defoliation of all tree species slightly decreased up to 21.7% (22.1% in 2017). 15.5% of all sample trees were not defoliated (class 0), 66.0% were slightly defoliated and 18.5% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers slightly increased up to 22.4% (22.2% in 2017) and slightly decreased for broadleaves up to 20.6% (21.9% in 2017).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 39% of all sample trees annually. Mean defoliation of *Pinus sylvestris* slightly increased up to 23.8% (23.0% in 2017), while in 2008-2018 there was observed a slightly increasing trend in 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 16.7% (18.9% in 2016) and the proportion of trees in defoliation classes 2-4 was 4.6% comparing with 7.4% in 2017.

The condition of *Fraxinus excelsior* remained the worst among all observed tree species. This tree species had the highest defoliation since 2000. Mean defoliation increased to 34.0% (32.5% in 2017). The share of trees in defoliation classes 2-4 decreased to 38.7% (41% in 2017).

25% of all sample trees had some kind of identifiable damage symptom. The most frequent damage was caused by abiotic agents (about 7%) in the period of 2011–2018. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (44%), *Populus tremula* (40%), *Alnus incana* and *Picea abies* (33%), the least for *Alnus glutinosa* (14%) and *Betula* sp. (18%).

In general, the mean defoliation of all tree species has varied inconsiderably from 1997 to 2018 and the growing conditions of Lithuanian forests can be defined as relatively stable.

Level II monitoring results show no significant changes in tree condition and environmental conditions over the last few years.

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

Žemaitis P, Žemaitė I (2018) Does butt rot affect the crown condition of Norway spruce trees? Trees – Structure and Function, 32 (2): 489–495. doi: 10.1007//s00468-17-1645-0

Armolaitis K, Stakėnas V, Varnagirytė-Kabašinskienė I, Gudauskienė A, Žemaitis P (2018). Leaching of Organic Carbon and Plant Nutrients at Clear Cutting of Scots Pine Stand on Arenosol. Baltic Forestry 24 (1):50–59. ISSN 2029-9230.

Outlook

Forest monitoring activities in Lithuania will continue (Level I and Level II) and no significant changes are planned for 2019.

In 2018-2019, the implementation of soil monitoring is planned on Level II monitoring plots.

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

Until 2018, the department of Forest Health at NIBIO has been responsible for the forest monitoring in Norway and has worked in close cooperation with the departments of Terrestrial Ecology, Forest and Climate and the National Forest Inventory (NFI). Norway is represented in 6 Expert Panels (Soil, Foliage, Crown, Growth, Vegetation and Deposition), in the Working Group QA/QC, and is holding the co-chair in EP Crown. In 2018 we participated in the ICP Forests Scientific Conference and Task Force meeting in Riga (May) and in the PCG meeting in Berlin (November).

Level I

In 2017, the Norwegian national forest monitoring was conducted on 2 591 observation plots on a systematic grid of 3 x 3 km in forested areas of the country. The plots are part of the NFI, which also is responsible for crown condition assessments. Defoliation assessments were carried out on 10 676 trees (Norway spruce and Scots pine) on 1 873 plots, damage assessments on 19 737 trees (all species) on all plots. A national field calibration course with 25 participants from the NFI was arranged for the monitoring in May 2018. In 2018, 626 plots were part of the transnational ICP Forests Level I grid (16 x 16 km = 1 plot pr. 256 km^2), and crown and damage data for 6 072 trees belonging to 22 species were reported to the ICP Forests database.

Level II

At our three Level II sites, the following surveys are conducted: crown condition and damage, tree growth, foliar chemistry, ground vegetation, soil solution chemistry and atmospheric deposition in bulk and throughfall. Chemical analyses are carried out in-house. Ambient air quality (incl. ozone) is measured at two plots (Birkenes and Hurdal) and meteorology at one (Birkenes) by the Norwegian Institute for Air Research (NILU). Data from the Level II surveys carried out by NIBIO are reported to ICP Forests annually.

We also reported data to ICP Integrated Monitoring in 2018.

Major results/highlights

National large-scale forest monitoring

2018 was the sixth year in Norway with the revised sampling design for Level I where annually one fifth of the NFI plots are monitored with five year revision intervals on the plots, following the rotation of the NFI. From 2013 on we have carried out defoliation assessments only for *Picea abies* and *Pinus sylvestris*, while damage assessments are carried out for all tree species present on the plots. This design produces good estimates of average national crown condition; however estimates of regional crown condition are probably less accurate, and bias due to changes in field teams are more likely to occur. The annual rotation of plots may also lead to accidental shifts in age structure of the assessed trees, resulting in an overestimated age effect on the results.

In 2018, the mean defoliation for *Picea abies* was 15.7%, and 13.2% for *Pinus sylvestris* in our national grid. Defoliation decreased for both spruce and pine, with 1.8%-points for spruce and 1.4%-points for pine compared to 2017.

Of all the coniferous trees, 48.8% were rated not defoliated in 2018, which is a bettering and an increase of 3%-points compared to the year before. 47.4% of the *Pinus sylvestris* trees were rated as not defoliated which is an increase of 3%-points. 50.0% of all Norway spruce trees were not defoliated, which is an increase of 3.4%-points compared to the year before.

We observed 6.2% discoloured trees for *Picea abies*, and 4.4% for *Pinus sylvestris*, representing a 1%-point decrease of discoloured trees for Norway spruce from the year before, but an increase of 1.8 %-points for Scots pine.

The mean mortality rate for the conifers was 0.25% in 2018 with 0.29% for spruce and 0.19% for pine.

The year 2018 was characterised by weather extremes in southern Norway (which covers most of the area south of Trondheim) resulting in different types of forest damage: A long winter lasting from November 2017 until April 2018 with large amounts of snow led to an unusually high frequency of snow damage and crown breakage. Spring was almost absent, and in May an almost four months long drought period started. According to the Norwegian Meteorological Institute the temperature in May 2018 in south-eastern Norway was 6–7 degrees higher than the normal mean temperature in this region (standard reference period 1961–1990), and in the summer months (June – August) it was 2–3 degrees higher than normal. Precipitation was as low as 25–50% of the normal during these months, resulting in a serious drought over large parts of southern Norway and about 2000 registered wildfires in both forests and agricultural land. In August several incidents of unusually heavy winds in south-eastern Norway caused a lot of storm felling. Further in-depth analysis of our national forest monitoring data will probably reveal a higher than normal frequency of damage related to snow, drought and storm in southern Norway, however, due to the early start of the NFI in June, drought symptoms may first become obvious in 2019.

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

Timmermann V., Andreassen K., Brurberg MB., Clarke N., Herrero ML., Jepsen JU., Vindstad OPL., Solheim H., Strømeng GM., Talgø V., Wollebæk G., Økland B., Aas W (2018) Skogens helsetilstand i Norge. Resultater fra skogskadeover-våkingen i 2017. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2017.] NIBIO Rapport 4(102) 2018. 84pp. ISBN 978-82-17- 02156-8

Outlook

- Monitoring at Level I will continue as part of our national monitoring conducted by the NFI.
- Provided that we will receive some extra funding, we are planning to restart our northernmost Level II site (Svanhovd, closed down in 2004), located close to the Russian border at 68°27' N. Future measurements at this plot would also be valuable for reporting under the NEC-directive.
- The planned installation of an ICOS C-flux tower at one of our Level II sites (Hurdal) was delayed, but will most likely be completed during 2019. At this site NILU also has one of their EMEP sites, opening up for a broad collaboration between ICOS, EMEP and ICP Forests.

Poland

National Focal Centre

Paweł Lech and Jerzy Wawrzoniak, Forest Research Institute (IBL)

Main activities/developments

The Forest Research Institute is responsible for carrying out all forest monitoring activities in Poland and closely co-operates with the Ministry of Environment (MŚ), the General Inspectorate of Environmental Protection (GIOŚ) and State Forests Enterprise (LP) in that matter. Poland is represented in 6 Expert Panels (Soil & Soil Solution; Forest Growth; Biodiversity; Crown Condition and Damage Causes; Deposition; Meteorology, Phenology & LAI) as well as in the Working Group QA/QC in Laboratories, where our representative holds the co-chair position.

Level I

In 2018, the forest condition survey was carried out on 2 023 Level I plots (8 km x 8 km grid) and a total number of 40 460 trees was assessed. Out of that, results of the assessment made on 348 plots on a 16 km x 16 km grid (European network) from about 6 960 trees were submitted to the ICP Forests database. Field work took place in July and August.

Level II

At 12 Level II plots the measurements of weather parameters, air quality as well as the chemical analysis of deposition (open field and throughfall) and soil solution was performed. Additionally, on 4 plots with 4 major tree species (Scots pine, Norway spruce, beech and oak) continuous measurements of dbh and water availability to trees were made.

Major results/highlights

Level I

The average total defoliation of all species amounted to 22.4%, that of coniferous trees in total to 22.4% and of deciduous trees in total to 22.3%. The percentage of healthy trees (with defoliation below or equal to 10%) of all species amounted to 11.3%, and the percentage of damaged trees (with defoliation over 25%) to 18.7%.

Deciduous species were characterized by a higher share of healthy trees (14.8%) and a higher share of damaged trees (21.1%) than coniferous species (respectively: 9.3% and 17.2%). The share of trees from the early warning class (slightly damaged trees, with defoliation of between 11% and 25%) amounted to: for all species – 70.1%, for coniferous species – 73.5%, and for deciduous species – 64.1%.

With regard to the three main coniferous species, *Abies alba* remained the species with the lowest defoliation (24.2% trees in class 0, 15.7% trees in classes 2-4, mean defoliation amounting to 20.3%). *Pinus sylvestris* was characterized by a lower share of trees in class 0 (8.3%), almost the same share of trees in classes 2-4 (16.9%) and a higher mean defoliation (22.3%) than *Abies alba*. *Picea abies* was characterized by a higher share of trees in classes 2-4 (22.6%) and the highest mean defoliation (24.3%) compared to Scots pine and fir. The percentage of healthy Norway spruce trees (with defoliation of up to 10%) amounted to 11.4%.

In 2018 as in the previous survey, the highest defoliation amongst broadleaved trees was observed in *Quercus* spp. A share of 4.4% of oaks was without any symptoms of defoliation and 36.3% was in defoliation classes 2-4, the mean defoliation amounted to 26.0%. A little better condition was observed for *Betula* spp. (8.1% trees without defoliation, 23.1% damaged trees (classes 2-4) and the mean defoliation amounted to 24.0%). *Fagus sylvatica* remained the broadleaved species with the lowest defoliation. In 2018 a share of 28.2% of beech trees was without any symptoms of defoliation, only 6.9% were in defoliation classes 2-4, the mean defoliation amounted to 16.9%. *Alnus* spp. was little more defoliated (21.1% trees without defoliation, 11.4% trees in classes 2-4, the mean defoliation amounted to 19.7%) than *Fagus sylvatica*.

In 2018, condition of assessed trees remained almost the same as compared to the previous year. Only damage of alder decreased, the share of trees without any symptoms of defoliation increased for this species by 7.3 percent points, the share of trees defoliated by more than 25% decreased by 1.9 percent points.

Level II

Meteorological measurements on 12 Level II plots revealed that 2018 was very dry, especially in the beginning of the vegetation period, i.e. in May and June. For both the vegetation period and the entire year, the sum of precipitation in 2018 was much lower (by half in some locations) compared to wet 2017 and very similar to the extremely dry and hot Poland 2015.

Results of deposition and concentration of elements in soil solution on 12 Level II plots will be evaluated in the second half of 2019. Concentration of SO_2 in ambient air in 2018 was higher from 3% to 71% than in 2017 and concentration of NO_2 from 2 to 57% despite a generally decreasing tendency of gaseous pollutants on most of the plots in recent years.

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

Sztabkowski K, Jonczak J, Zawartość JW (2018) Cu, Mn i Zn w glebach powierzchni monitoringu intensywnego na obszarze Polski północnej i środkowej. (Content of CU, Mn i Zn in soils on Level II plots in northern and central Poland). Sylvan R. CLXII (9): 745-753, 2018, DOI: 10.26202/sylwan.2018044

Outlook

Besides the routine monitoring activities the following projects launched in 2018 and 2019 are now being performed with the use of forest monitoring data and/or infrastructure:

- Evaluation of acidification and euthrophication of forest ecosystems in Poland in respect to the critical load concept;
- Water cycle in forest ecosystems under climate change conditions;
- Coefficients of dieback/survivorship of trees on the forest monitoring Level I plots in Poland in the years 2007-2017 and their usability in health condition assessment of major forest tree species.

Romania

National Focal Centre

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

Main activities/developments

In 2018, a special event - The International Scientific Conference “Forest Science for a Sustainable Forestry and Human Well-being in a Changing World” - INCDS “Marin Drăcea” 85 Years of Activity, Centenarian of the Great Union in 1918” was organised. This event was supported by prestigious scientific institutions - IUFRO, ICP Forests, the Romanian Academy and the Academy of Agricultural and Forestry Sciences “Gheorghe Ionescu Sisești”. Most of the scientific sessions referred to ICP Forests research tasks: climate change, the impact of air pollution or of biotic and abiotic stressors on forests, adaptive management, modelling and mapping of forest ecosystems and their services or new Earth-Observation technologies applied in forests. The scientific presentations debated issues of actuality in forest science and its role in promoting sustainable forest management and an improvement of quality of life, in the global context of environmental changes.

Also, in accordance with the ICP Forests activities the Romanian forest monitoring experts participated in the following events:

- The 34th Task Force Meeting of ICP Forests and the 7th ICP Forests Scientific Conference, Riga, Latvia, 21-24 May 2018
- The ICP Forests Joint Expert Panel Meeting in Zvolen, Slovakia, 1-5 October 2018
- The 5th Forum Carpaticum "Adapting to Environmental and Social Risk in the Carpathian Mountain Region", Eger, Hungary, 15-18 Oct. 2018
- The UNECE - ICP Forests 14th Ozone Intercalibration Course, held in Poreč, Croatia, 10 - 13 Sept 2018
- The International Conference on Ozone and Plant Ecosystems, Florence, Italy, 21-25 May 2018.
- The 9th ICP Forests Soil Interlaboratory Comparison in 2018, 1 January to 1 October 2018, Online.

The forest monitoring data collection and analysis was carried out in both Level I and Level II monitoring networks as follows:

- Annual crown condition assessments on Level I plots (245 permanent plots)
- Forest monitoring activities on Level II plots: 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)
- Chemical analysis for deposition samples, air pollutants passive samples (O_3, NO_2, NH_3) and foliar nutrients
- Validating and submitting the database for all monitoring activities (Level I and Level II).

Additionaly within the EO-ROFORMON project (www.eo-roformon.ro) a new monitoring network has been developed and specific forest stand biometrics characteristics were determined using Terrestrial Laser Scanning and classical measurements including the assessment of some physiological parameters of trees. This project aims to prototype a novel national forest monitoring and forecasting system based on the integration of active (radar) and passive (optical) Earth-Observation (EO) sensors calibrated with in situ data obtained from terrestrial laser scanning thus avoiding one of the main criticisms with respect to the ICP Forests network, the consistency of assessments.

Major results/highlights

In 2018, the forest condition survey in Romania was carried out on the 16 x 16 km transnational Level I grid net, during 15 July and 15 September.

From the total number of 5832 assessed trees in 243 permanent plots, 1051 trees were conifers (18%) and 4781 broadleaves (82%), 50% were rated as healthy (defoliation class 0), 36.3% as slightly defoliated (class 1), 11.7% as moderately defoliated (class 2), 1.4% as severely defoliated (class 3) and 0.6% were dead (class 4).

The overall share of damaged trees (defoliation classes 2-4) was 13.7%, with 0.5 percent lower than in 2017. For conifers a percentage of 12.7% of the assessed trees was classified as damaged (defoliation classes 2-4) with 0.2 percent higher than in 2017. *Picea abies* was the least affected coniferous species with a share of damaged trees of 10.4%, whereas *Abies alba* had 13.0%.

For broadleaves, 13.9% of the trees were recorded as damaged (defoliation classes 2-4) with 1.1 percent lower than in 2017. Among the main broadleaves species, *Fagus sylvatica* and *Carpinus betulus* had the lowest share of damaged trees (8.8% and 9.1%, respectively). For all *Quercus* spp. (*Q. petraea*, *Q. cerris*, *Q. robur*, and *Q. frainetto*) a share of 20.7% from the total number of the assessed trees, were damaged. Similar to the previous year, *Fraxinus excelsior* was the most affected broadleaved species (34.5%), due to defoliating insects and fungi damages recorded in the northeastern part of the country.

Damage symptoms were reported for 25.9% of the conifers and 37.2% of the broadleaves, respectively. The most important causes were attributed to defoliators and xylophages insects (62.6%) and fungi (9%).

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

Badea O, Apostol E, Teodosiu M, Chira D, Dinca L, Olenici N (2018) The anniversary conference "Forest science for a sustainable forestry and human well-being in a changing world"-Bucharest, September 18-21, 2018. Annals of Forest Research 61(2):127. doi:10.15287/afr.2018.1184.

Popa I, Leca S, Badea O (2018) Forest Conditions. Measuring and interpreting changes in stem increment - ICP Forests 2017 Executive Report, Section 3.2, pp.9-11. ISSN 1020-587X, e-ISSN 2198-6541

Dinca L, Badea O, Guiman G, Braga C, Crișan V, Greavu V, Murariu G, Georgescu L (2018) Monitoring of soil moisture in Long-Term Ecological Research (LTER) sites of Romanian Carpathians. Annals of Forest Research. doi:10.15287/afr.2018.1188.

Apostol B, Chivulescu S, Ciceu A, Petrila M, Pascu I, Apostol E, Leca S, Lorent A, Tanase M, Badea O (2018) Data collection methods for forest inventory: a comparison between an integrated conventional equipment and terrestrial laser scanning. Annals of Forest Research 61(2), 189-202. doi:10.15287/afr.2018.1189

Nechita C, Eggertsson O, Badea O, Popa I (2018) A 781-year oak tree-ring chronology for the Middle Ages archaeological dating in Maramureș (Eastern Europe). Dendrochronologia 52:105-112. doi:10.1016/j.dendro.2018.10.006

Zhang L.,Hoshika Y, Carrari E, Badea O, Paoletti E (2018) Ozone risk assessment is affected by nutrient availability: Evidence from a simulation experiment under free air-controlled exposure (FACE). Environ Pollut 238:812-822, doi:10.1016/j.envpol.2018.03.102

Dunford R, Harrison P, Smith A, Dick J, Antunes P, Aszalos R, Badea O, Baro F, Berry P et al. (2018) Integrating methods for ecosystem service assessment: Experiences from real world situations. Ecosystem Services 29:499-514. Part: C, doi: 10.1016/j.ecoser.2017.10.014

Dick J, Turkelboom F, Woods H, Iniesta-Arandia I, Primmer E, Saarela SR, Bezak P, Mederly P, Vadineanu A, van der Wal JT, Arany I, Badea O, Bela G, Boros E et al. (2018) Stakeholders' perspectives on the operationalisation of the ecosystem service concept: Results from 27 case studies. Ecosystem Servies 29:552-565, Part: C, doi: 10.1016/j.ecoser.2017.09.015

Calzone A, Podda A, Lorenzini G, Maserti BE, Carrari E, Deleanu E, Hoshika Y, Haworth M, Nalia C, Badea O, Pellegrini E, Fares S, Paoletti E (2018) Cross-talk between physio-logical and biochemical adjustments by *Punica granatum* cv. Dente di cavallo mitigates the effects of salinity and ozone stress. Science of The Total Environment, doi:10.1016/j.scitotenv.2018.11.402.

The Annual Report of the Romanian Environment Status in 2017

The Annual Report of the Romanian Forest Status in 2017,

ICP Forests 2017 Technical Report

Report of monitoring sites and indicators in accordance with the new NEC Directive.

Outlook

The forest monitoring activity in Romania is supported by several research projects as Nucleu Progam - BIOSERV (financed by the Romanian Ministry of Research and Innovation) or Life15 MOTTLES project and a new INFRADEV H2020 project proposal has been submitted (in partnership with other members of LifeWatch ERIC).

Dr. Ovidiu Badea, Dr. Stefan Leca

Serbia

National Focal Centre

Dr Ljubinko Rakonjac, Principal Research Fellow, Institute of Forestry, Belgrade

Main activities/developments

The National Focal Center at the Institute for Forestry has been continuously participating in the international programme ICP Forests with the tendency to achieve further improvement and harmonization with other approaches to monitoring the state of forests and forest ecosystems. Monitoring is conducted on 130 Level I sample plots and 5 Level II observation plots. The main activities in 2018 included the improvement of the work within the project of monitoring the impact of transboundary air pollution on forest ecosystems on the territory of the Republic of Serbia through the implementation of new and enhancement of existing infrastructures with the application of modern technologies and strengthening the cooperation with all relevant institutions in the field of forestry: forest estates of SE `Srbijašume`, National Parks, as well as forest owners.

Major results/highlights

The results on the defoliation of broadleaved species obtained on 130 Level I sample plots in the Republic of Serbia in 2018 are as follows: 69.6% of trees with no defoliation, 18.3% of trees with slight defoliation, 9.5% with moderate defoliation 2.5% of trees with severe defoliation and 0.1% of dead trees. Conifers had 81.6% of trees with no defoliation, 8.2% of trees with slight defoliation, 6.2% of trees with moderate defoliation, 4.0% of trees with severe defoliation and 0.0% of dead trees.

The main results obtained after processing all the data collected on the territory of the Republic of Serbia within the ICP Forests programme from 2003 to 2018 (Level I and Level II) indicate that several consecutive years (2011-2013) recorded extreme weather events (high temperature without precipitation) in a long period of time (drought) that contributed to the die-back of both individual trees and larger forest surface areas. These events made favourable conditions for the occurrence of secondary agents of damage (e.g., bark beetles). The year of 2013 was recorded as the year with unprecedented die-back of forests in Serbian forestry.

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

All National publications are available at our site: http://www.forest.org.rs/?icp-forests-serbia

Gagić-Serdar R, Stefanović T, Đorđević I, Češljar G, Marković M (2018) Forest vitality (ICP Forests Level I sample plot) with a special emphasis on biotic agents in the Republic of Serbia in 2018. Sustainable Forestry, tom 77-78. Institute for Forestry, Belgrade. ISSN 1821-1046, UDK 630, p.55-65. http://www.forest.org.rs/files/Sustainable%20Forestry%20-Ozbornik%20radova%2077-78.%202018.%20godina.pdf

Tomislav S, Gagić Serdar R, Đorđević I, Češljar G, Momirović N, Živanović I, Nevenić R (2017) Studies of defoliation on ICP Forests plots Level I in the Republic of Serbia. Sustainable Forestry, tom 75-76 Institute for Forestry, Belgrade. ISSN 1821-1046, UDK 630, p.41-56. http://www.forest.org.rs/files/Sustainable%20Forestry_zbornik-radova%2075-76-2017.%20godina.pdf

Češljar G, Gagić Serdar R, Đorđević I, Poduška Z, Stefanović T, Bilibajkić S, Nevenić R (2014) Analysis of types of damages at the sample plots of Level I in 2013 on the territory of the Republic of Serbia. Časopis Sustainable Forestry, tom 69-70, Institut za šumarstvo, Beograd. ISSN 1821-1046. UDK 630, p.63-71. http://www.forest.org.rs/files/Sustainable%20Forestry%20-%20Collection%20of%20works%2069-70,%20year%202014.pdf

Češljar G, Nevenić R, Bilibajkić S, Stefanović T, Gagić Serdar T, Đorđević I, Poduška Z, (2013) Viability of trees on bio-indicator plots Level A I in the Republic of Serbia in 2013. Časopis Sustainable Forestry, tom 67-68, Institut za šumarstvo, Beograd. ISSN 1821-1046. UDK 630, p. 69-78. http://www.forest.org.rs/pdf/SUSTAINABLE_FORESTRY_Zbornik-radova_tom_67-68_2013_godina.pdf

Outlook

In the past years, the project on monitoring the impact of transboundary air pollution on forest ecosystems on the territory of the Republic of Serbia has encountered certain problems in the collection, storage and processing of data, as well as in the data encoding. Problems were also noted in the further process of information gathering and inefficiency in their subsequent processing and use for further comparative analyses. At the level of strategic management of the data obtained and their use in other areas, certain shortcomings of insufficient cooperation were noted, both with decision-makers and institutions that could use the data, which is connected with the lack of an adequate information system and digital devices. There are no information tools that can be used to collect, forward and properly integrate all the information that is important for the monitoring of forest ecosystems in the Republic of Serbia at Levels I and II. The existing National Digital Database includes only the data collected on Level I sample plots, while the database, i.e. digital data for Level II sample plots have not been entered at the national level because the national database for Level II has not been formed yet.

In order to minimize or eliminate these problems and deficiencies, the future development of the work infrastructure in this project must involve the use of modern technologies in data collection directly in the field, i.e. the use of special tablets and appropriate software and hardware solutions for entering and processing the collected data. The use of modern technologies in forest monitoring will enable more efficient and accurate data collection in the field. With the use of tablet computers, each group of researchers will have the opportunity to enter data on all the listed characteristics of Level I and Level II sample plots directly in the field. This approach will enable a unified way of collecting data in the field and will eliminate all the shortcomings of the previous work. Apart from the information on the characteristics of sample plots prescribed by the manual, additional data can be obtained such as images of sample plots, types and intensities of individual damage, and precise data (coordinates) on the work of each team of researchers can be obtained. So far in the collection, only conventional methods of field recording have been used in processing and analysis of Level I and II sample plot data, and these have to be encoded after each field visit. By applying these technologies it will be possible to record data directly in the field, and then enter them through the software and hardware systems directly into the database, without unnecessary typing, which often produces errors.

The future project aims to establish an appropriate information system through the realization of the following activities:

- introduction of hardware and system software;
- establishment of a database server at the Institute of Forestry;
- installation of system software and database management software;
- development of the database and applications;
- development and installation of the database;
- encoding of the existing manual;
- creation of a purposeful application for data entering, processing, distributing and analyzing;
- creation of an appropriate operational procedure for data entering and distributing;
- testing the application and the system functionality;
- team training for data entering, processing and distribution.

Slovakia

National Focal Centre

Pavel Pavlenda, National Forest Centre – Forest Research Institute Zvolen (NFC-FRI)

Main activities/developments

In October 2018, Slovakia hosted the Joint Expert Panel Meeting of ICP Forests (EP Meteorology, Phenology and LAI; EP Biodiversity and Ground Vegetation; EP Forest Growth and EP Ambient Air Quality). Field courses for phenological assessment and assessment of visual symptoms of ozone damage were also included in the event in Zvolen. A bilateral seminar (Slovakia, Czechia) focussed on applied forest ecology and monitoring of forests was organized in June 2018 in Mala Fatra Mts.

Standard crown condition assessment on Level I plots (16 x 16 km grid) was conducted within 4 weeks of July and August (3 teams in parallel). Activities of intensive monitoring continue on 6 Level II monitoring plots with a frequency of twice per month. Defoliation, increment, atmospheric deposition and meteorology are monitored at all these Level II plots but other surveys (soil solution, air quality, litterfall) are limited only to selected plots.

In the first half of the year 2018 we cooperated in the elaboration of the national report for the NEC directive implementation (Proposal of a monitoring network to monitor the impact of air pollution on ecosystems to meet NECD criteria - explaining document, SAŽP).

Current research activities focus also on nutrient pools and nutrient balance in forest ecosystems as supporting basis for the elaboration of Forest Bioenergy Guidelines (soil sustainability aspects). Several national research projects have been submitted to support research of specific topics related to forest ecology and activities of forest monitoring.

Major results/highlights

The 2018 national crown condition survey was carried out on 101 Level I plots of the 16x16 km grid. The assessments covered 4402 trees, 3715 of which were assessed as dominant or co-dominant trees according to Kraft. Of the 3715 assessed trees, 42.6% were damaged (defoliation classes 2-4). The respective figures were 49.7% for conifers and 38.2% for broadleaved trees. Compared to 2017, the share of trees defoliated more than 25% increased by 10.7 percent points. Mean defoliation for all tree species together was 27.4%, with 29.9% for conifers and 25.8% for broadleaved trees.

After continuous increase of mean defoliation in the years 2006-2014, substantial interannual changes were detected in the last years for the main broadleaved tree species (beech, oak, hornbeam). The fluctuation of defoliation depends mostly on meteorological conditions. In 2013, the mean defoliation of broadleaved trees species was for the first time as high as of conifers but in the next years the mean defliation of conifers was again higher than mean defoliation of broadlaeved tree species. In 2018, the highest mean defoliaton was detected for black locust, ash and Scotch pine.

Radial increment of European beach, hornbeam and Scots pine has decreased (correlated with defoliation increase) in the last two decades while increment of Norway spruce and oaks is relatively stable. Specific results are for Norway spruce: defoliation and increment of surviving trees is without increasing or decreasing trend but a large number of trees died very rapidly due to bark beetle outbreaks which led to a drop in the number of assessed trees. Silver fir is the tree species with a slightly positive trend of defoliation and increment and shows recovery after decline in the 1980th.

Deposition of sulphur and nitrogen does not show further decrease in the last decade. The annual deposition of sulphur (in throughfall) varies betwwen 3 and 9 kg ha^{-1} on monitoring plots, the annual deposition of nitrogen (in throughfall) varies betwwen 5 and 10 kg ha^{-1}.

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

In 2018, the thematic double issue of the Central European Journal of Forestry was devoted to the 100th Anniversary of the first Czechoslovak Republic (October 28, 1918). Three common scientific articles of authors from Slovakia and Czechia related to forest monitoring were published in the special issue:

Sitková Z, Sitko R, Vejpustková M, Pajtík J, Šrámek V (2018) Intra- and interannual variability in diameter increment of *Fagus sylvatica* L. and *Picea abies* L. Karst. In relation to weather variables. Central European Forestry Journal 64:223-237. doi: 10.1515/forj-2017-0044

Pajtík J, Čihák T, Konôpka B, Merganičová K, Fabiánek P (2018) Annual tree mortality and felling rates in the Czech Republic and Slovakia over three decades. Central European Forestry Journal 64:238-248. doi: 10.1515/forj-2017-0048

Krupová D, Fadrhonsová V, Pavlendová H, Pavlenda P, Tóthová S, Šrámek V (2018) Atmospheric deposition of sulphur and nitrogen in forests of the Czech and Slovak Republic. Central European Forestry Journal 64:249-256. doi: 10.1515/forj-2017-0050

Outlook

We intend to continue with the monitoring activities at all Level I plots and the remaining 6 Level II sites. With current funding levels we have no plans to expand our monitoring activities beyond this. One of Level II plots (Polana – Hukavsky grun) with surrounding research plots is a site of LTER. This plot has the longest time series (since 1991 for most parameters) and it is the priority plot for renovation and innovation of the infrastructure. However, the development of the field infractructure as well as the laboratory instruments depends on the success of submitted projects.

The good prospects are for soil data management and a publication of results from the BioSoil project and from subset of NFI plots due to a national project on forest soils that passed the call in 2018.

Slovenia

National Focal Centre

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

Main activities/developments

In 2018, 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 1056 trees, 362 coniferous and 694 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 2018, deposition and soil solution monitoring was performed on all four Level II core plots. On nine plots the ambient air quality monitoring (ozone) was done with passive samplers and ozone injuries assessed. On all plots the phenological observations were carried out. On six plots growth was monitored with mechanical dendrometers.

Major results/highlights

- Mean defoliation of all tree species was estimated at 27.4% (compared to last year the situation deteriorated).
- Mean defoliation in 2018 for coniferous trees was 27.7% (in 2017 it was 28.6 %).
- Mean defoliation 2018 for broadleaves trees was 27.2% (in 2017 it was 26.9 %).
- The share of trees with more than 25% defoliation (damaged and dead trees) in 2018 increased compared to 2016 from 33.8% to 36.1%, but slightly decreased compared to 2017.
- Percent of damaged broadleaves trees decreased from 35.1% in 2017 to 33.9% in 2018.
- Percent of damaged coniferous trees slightly decreased from 40.6% in 2017 to 40.3% in 2018. In 2018 the coniferous forests are still strongly damaged by insects.
- Defoliation of coniferous trees in 2018 remained on a very high level. The main reason is the bark beetle outbreak in summer 2016, stretching all over 2017 and 2018.
- Average ozone concentrations in the growing season of 2018 were from 27 to 74 $\mu g/m^3$ on monitored plots which is slightly lower (around 2 $\mu g/m^3$) than in 2017. On 5 out of 9 plots the average 14-days ozone concentration ascended over 80 $\mu g/m^3$ during the growing season at least in one period. On additional two plots the highest concentration was very close to 80 $\mu g/m^3$.
- The highest average 14-days concentration was 93 $\mu g/m^3$ and 74 $\mu g/m^3$ on average on the most ozone-polluted plot.
- On three Level II core plots total nitrogen (N) in bulk decreased (8 – 23% to previous year). On one plot it increased for 15%. Sulphur (S) slightly increased or decreased on all four plots.
- Total nitrogen in throughfall decreased on one plot, on one plot it stagnated but increased on two plots. The same trend is shown for sulphur.

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

Mongus D, Vilhar U, Skudnik M, Žalik B, Jesenko D (2018) Predictive analytics of tree growth based on complex networks of tree competition. For Ecol Manage 425: 164-176. doi: 10.1016/j.foreco.2018.05.039.

Vilhar U, De Groot M, Žust A, Skudnik M, Simončič P (2018) Predicting phenology of European beech in forest habitats. IForest 11: 41-47. doi: 10.3832/ifor1820-010.

Ferlan M, Grah A, Kutnar L, Ogris N, Planinšek Š, Rupel M, Simončič P, Sinjur I, Skudnik M, Žlindra D, Žlogar J (2018) LOGAR, Jure. Poročilo o spremljanju stanja gozdov za leto 2017: vsebinsko poročilo o spremljanju stanja gozdov v l. 2017 v skladu s Pravilnikom o varstvu gozdov (2009)//Forest monitoring report for the year 2017//. Ljubljana: Gozdarski inštitut Slovenije, 2018. VI, p. 79. http://dirros.openscience.si/IzpisGradiva.php?id=8403, http://www.gozdis.si/data/publikacije/2018/20180629_StanjeGozdov2017.pdf.

Outlook

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

Spain

National Focal Centre

Ana Isabel González, Forest Inventory and Statistics Department
Belén Torres, Subdirectorate-General of Forest Policy
Elena Robla, Directorate General of Rural Development, Innovation and Forest Policy

Ministry of Agriculture, Fisheries and Food of Spain

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 carried out successfully in 2018.

Main activities were:

- May 2018: National Intercalibration Course.
- May 2018: Attendance to Task Force Meeting of ICP Forests and 7th ICP Forests Scientific Conference (Riga, Latvia)
- October 2018: Attendance to ICP Forests Combined Expert Panel Meeting (Zvolen, Slovakia)
- Others: Continuously updating website

Major results/highlights

Level I

Regarding the year 2017, the results obtained in 2018 show an improvement of the health condition of the trees surveyed. The percentage of healthy trees increases (77.3%, compared to 72.2% in 2017), and damaged trees decreased (20.6% of the trees with defoliation higher than 25%, while in 2017 this percentage was 24.8%). The percentage of dead or missing trees has decreased as well (2.2% in 2018 compared to 3% in 2017). The mortality of trees is mainly due to felling operations, like sanitary cuts and forest harvesting processes.

Both conifers and broadleaves show improvement, and this is more evident in the latter, since the percentage of healthy trees increases to a high proportion (77.6% compared to 70.7% in 2017); and the percentage of damaged broadleaves decreases to 20.7% of the trees. In the case of conifers, the percentage of healthy trees increases (77% compared to 73.8% in 2017), with the percentage of damaged also decreasing considerably to 20.4% of trees in this category, a figure similar to the broadleaves.

In 2017, it was pointed out that the high deforestation ratios recorded could be related to the fact the drought periods in Spain become longer and more extreme. It was said as well that an improvement of the situation was expected when drought ended, as effectively happened in 2018. However, probably, the recover period will be long and last several years, since, although defoliation ratios are better than in the last year, figures are still worse than the average of the last 5 years.

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[1]

- Forest Damage Inventory 2018 (*Inventario de Daños Forestales 2017*)
- Maintenance and Data Collection. European large-scale forest condition monitoring (Level I) in Spain: 2018 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 2018*).

Level II[2]

- European intensive and continuous monitoring of forest ecosystems, Level II. 2017 Report. (*Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II*).

Spanish versions are available for download.

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[1] https://www.mapa.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimiento-bosques/red_nivel_l_danos.aspx

[2] https://www.mapa.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimiento-bosques/red_nivel_ll_danos.aspx

Outlook

Nowadays, data from ICP- Forests Level I 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 date to assess the variation of carbon in these forestry pools.

In adition, in 2018 Spanish Level II plots have been nominated to take part of the "Monitoring air pollution impacts System" stablished by National Emission Ceiling Directive (NECD). First reporting obligation will be on 1st July, 2019.

Moreover, regional surveys are being carried out by different regions (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 data bases. The result would be a considerable increase of Spanish sample. The National Institute for Agricultural and Food Research and Technology (INIA) is running a research to collect all the information available related to regional surveys, and then, to analyse and harmonize it in a national level. First results are expected to be ready along 2019.

Sweden

National Focal Centre

Sören Wulff, Swedish University of Agricultural Sciences (SLU)

Main activities/developments

Monitoring activities continued on Level I. A revised sampling design for Level I plots was implemented in 2009, where an annual subset of the Swedish NFI monitoring plots are measured. The Swedish NFI is carried out with a five years interval and accordingly the annual Level I sample is remearsured every fifth year. Defoliation assessments are carried out only on *Picea abies* and *Pinus sylvestris*, while damage assessments are done on all sample trees. The Swedish Throughfall Monitoring Network (SWETHRO) has delivered data on deposition, soil solution and air quality. Sweden organized the sixth "Saltsjöbaden" workshop - Clean air for a Sustainable Future – in March 2018.

Major results/highlights

The major results concern only forests of thinning age or older and outside forest reserves. The results show a reduced number of defoliated *Picea abies* during the last years. The proportion of trees with more than 25% defoliation is for *Picea abies* 18.6% and for *Pinus sylvestris* 11.2%. Large temporal annual changes are seen on regional level, however an improvement in defoliation is seen for *Picea abies* in northern Sweden for the last 10 years. For *Pinus sylvestris* a slight improvement in central Sweden is seen during the same period. The mortality rate in 2018 was for *Pinus sylvestris* 0.22% and for Picea abies 0.10%. The proportion of trees with an identifiable damage was 18.7%. For the main tree species *Pinus sylvestris* and *Picea abies*, this proportion was 13.7 %, which is about the same as for the last 5 years.

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

Johnson J, Graf Pannatier E, Carnicelli S, Cecchini G, Clarke N, Cools N, Hansen K, Meesenburg H, Nieminen TM, Pihl Karlsson G, Titeux H, Vanguelova E, Verstraeten A, Vesterdal L, Waldner P, Jonard M (2018) The response of soil solution chemistry in European forests to decreasing acid deposition. Global Change Biology 1–17. doi: 10.1111/gcb.14156

Karlsson PE, Akselsson C, Hellsten S, Pihl Karlsson G (2018) A bark beetle attack caused elevated nitrate concentrations and acidification of soil water in a Norway spruce stand. Forest Ecol Manage 422:338-344

Nussbaumer A et al. (2018) Impact of weather cues and resource dynamics on mast occurrence in the main forest tree species in Europe. For Ecol Manage 429:336-350. doi:10.1016/j.foreco.2018.07.011

Outlook

The Level I will continue as previously. Sweden will participate in the new EU National Emission Ceilings Directive (NEC Directive) on the reduction of national emissions of certain atmospheric pollutants. Data from a subset of Level I plots will be used in monitoring effects of air pollution on forests. Sweden will participate in the joint ICP Forests and ICP Vegetation expert workshop assessing and estimating ozone impacts on forest vegetation.

Switzerland

National Focal Centre

Peter Waldner, Swiss Federal Research Institute WSL

Main activities/developments

- We have continued combining visual assessments of crown condition by experts in the field with image analysis based on deep machine learning algorithms and will further continue to include remote sensing products into this approach. A first publication has been produced.

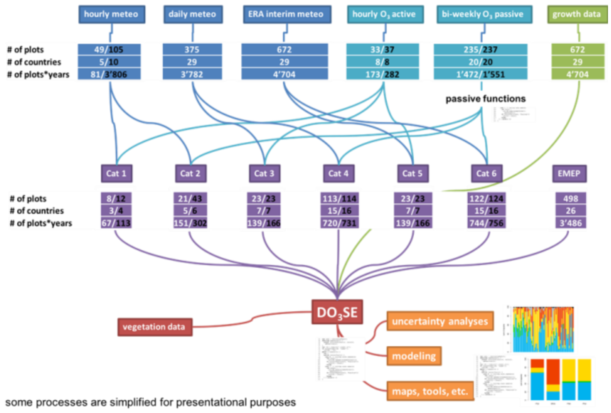
- We have continued the ozone risk assessment by means of ozone symptom assessment and ozone concentration measurements (with passive samplers and co-located ozone monitors) on seven Level II plots. Data have been submitted to the ICP Forests database.
- The 14th UNECE-ICP Forests Intercalibration Course on ozone symptom assessment, chaired by M. Schaub, was held in Poreč, Croatia, on 10-13 September 2018. 22 participants from 13 countries attended the course.
- In respect to the 2018 summer drought, we have pushed towards earlier data submission (incl. 2018 data) to make data available for the assessment of drought effects on parameters.
- Marcus Schaub has been assigned as chair of the ICP Forests Scientific Committee, co-chaired by Lars Vesterdal (http://icp-forests.net/page/scientific-committee).
- Marco Ferretti has been assigned as chair of ICP Forests.

Major results/highlights

After defoliation increased in 2017, the defoliation decreased again in 2018. The proportion of "significantly damaged trees" between 30% and 100% (class 2-4) decreased from 33.7% in 2017 to 23.5% in 2018. The basis for this data is the crown assessment for a total of 1039 trees on 47 plots in 2018. The percentage of significantly damaged trees in 2018 is back to values comparable to the observations in 2015 and 2016 (even slightly lower). The rather moist early spring in 2018 might be responsible for this observation. The hot dry summer period in 2018 did not affect the defoliation. This is most probably due to the fact that the crown assessment campaigns had already been completed before the effects of the extreme drought became apparent. In some areas of Switzerland, but locally highly heterogeneous, mainly beech but also other deciduous trees showed signs of early leaf senecense already at the end of July/ beginning of August. It needs to be carefully assessed if the hot drought in 2018 will have lagged effects on defoliation in 2019. The proportion of slightly defoliated trees (class 1) increased from 53.7% in 2017 to 57.9% in 2018, whereas the moderately defoliated ones (class 2) decreased from 21.5% to 12.5%. Moreover, the proportion of not defoliated trees increased form 12.5% in 2017 to 18.6% in 2018.

In January 2019, we published a study on the defoliation estimation by analyzing ground-level photos with deep machine learning algorithms. The algorithm was trained on a subset of photos where the defoliation was estimated by experts (in-situ and based on the photos), and then the algorithm was used to estimate the defoliation on another subset. Results are promising, and we aim to continue this research. Increasing the training material (i.e. the samples) is a possibility to increase the performance of the approach.

The study on "Predicting Ozone Fluxes, Impacts and Critical Levels on European Forests PRO$_3$FILE" has been further pushed forward. The study aims to make use of data from long-term monitoring plots across Europe where ozone concentrations have been measured since 2000, in parallel to forest and vegetation variables. Ozone-related effects and Critical Levels on selected endpoints such as tree growth will be derived by quantifying ozone fluxes and applying multiple and various statistical techniques that consider confounding abiotic and biotic environmental factors. More information can be found at https://www.wsl.ch/de/projekte/pro3file.html.



*Number of plots, countries and plot*years for each data source and category before (white) and after (black) the official call for hourly meteo data.*

Measured (ICP Forests, LWF, Sanasilva, Swiss NFI, NCEI) and modeled (Meteotest, EMEP, ECMWF) data sources from different national (LWF, Sanasilva, Swiss NFI) and international (ICP Forests, EMEP) networks, are combined to maximize sample size and diversity, i.e., to cover large gradients in forest types and in environmental conditions.

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

Cailleret M, Ferretti M, Gessler A, Rigling A, Schaub M (2018) Ozone effects on European forest growth – towards an integrative approach. Journal of Ecology. doi:10.1111/1365-2745.12941

Cailleret M (2018) Toward an Integrative Approach to Assess Ozone Impacts on Forest Growth. Blog of Journal of Ecology. https://jecologyblog.com/2018/03/07/ozone-impacts-on-forest-growth/

Didion M, Sutter F, Vollenweider P, Gessler A, Waldner P, Schaub M (2018) LWF-Tea bag sites; Swiss Federal Research Institute WSL; doi:10.16904/envidat.36, https://www.envidat.ch/dataset/lwf-tea-bag-sites

Djukic I, Kepfer-Rojas S, Kappel Schmidt I, Steenberg Larsen K, et al. (2018) Early stage litter decomposition across biomes. Science of the Total Environment. doi: 10.1016/j.scitotenv.2018.01.012

Hansen K, Schaub M, Prescher A-K, Seidling W (2018) European forests in a changing environment: Air pollution, climate change and forest management. Book of Abstracts, 7th ICP Forests Scientific Conference, 22–23 May 2018, Riga, Latvia, 73 pp.

Hartmann H et al. (2018) Research frontiers for improving our understanding of drought-induced tree and forest mortality. New Phytol 218:15–28

Kälin U, Lang N, Hug C, Gessler A. Wegner JD (2019) Defoliation estimation of forest trees from ground-level images. Remote Sens Environ 223:143–153

Nussbaumer A. et al. (2018) Impact of weather cues and resource dynamics on mast occurrence in the main forest tree species in Europe. Forest Ecol Manag 429:336–350

Rebetez, M. et al. (2018). Meteorological data series from Swiss long-term forest ecosystem research plots since 1997. Ann For Sci 75:41

Schaub M, Häni M, Calatayud V, Ferretti M, Gottardini E (2018) ICP Forests Brief No 3 - Ozone concentrations are decreasing but exposure remains high in European forests. Programme Co-ordinating Centre of ICP Forests, Thünen Institute of Forest Ecosystems. doi: 0.3220/ICP1525258743000

Van der Linde S, Suz L, Orme D, Cox F, Andreae H at al. (2018) Environment and host tree as large scale controls of ectomycorrhizal fungi. Nature. doi: 10.1038/s41586-018-0312-y

Outlook

- ICP Forests and ICP Vegetation joint meeting on ozone, 12 April 2019, WSL Birmensdorf, chaired by M. Ferretti
- 8th ICP Forests Scientific Conference, «Trends and events – Drought, extreme climate and air pollution in European forests», 12-13 June 2019, Ankara, Turkey, chaired by M. Schaub et al. (https://sc2019.thuenen.de/). The scope of the 8th ICP Forests Scientific Conference is inspired by the recent drought and other extreme events occurring across Europe in 2018. The main focus of the conference is therefore on forest ecosystem effects from recent and past extreme events caused by drought, heat, storms, frost and flooding. With "Trends and events - Drought, extreme climate and air pollution in European forests" we aim to promote the extensive ICP Forests data series to combine novel modeling and assessment approaches and integrate long-term trends with extreme weather events across European forests.
- Session B4g on "Long-Term Forest Monitoring Networks for Evaluating Responses to Environmental Change» at at the XXV IUFRO World Congress, Curitiba, Brazil on 29 Sept-5 Oct 2019, chaired by M. Schaub et al. (http://iufro2019.com/). This session aims to attract scientists, managers and stakeholders who are keen to understand large-scale, long-term effects of rapidly changing environmental drivers on forest ecosystems, to advance forest monitoring systems from local to global scale. The session offers the opportunity to present latest research findings, address methodological issues, and outline solutions based on the comprehensive data series from long-term forest monitoring networks world-wide, such as ICP Forests, EANET, ICOS, ILTER, TERN and others. A further objective is to provide a platform for networking and cooperation to support future synthesis studies across monitoring networks. Presentations on new advances based on airborne or satellite data are particularly welcome.

Peter Waldner, Marcus Schaub, Arthur Gessler, Simpal Kumar, Stefan Hunziker, Christian Hug

Turkey

National Focal Centre

Sıtkı Öztürk, Ministry of Forestry and Water Works, General Directorate of Forestry, Department of Combatting Forest Pests

Main activities/developments

Participation in the ICP Forests monitoring network in order to monitor the health of forests in our country and Level I Level II programmes were implemented based on the observation sites.

As of 2018:

- Every year, on 612 Level I and 52 Level II observation areas crown status and damage assessment visual assessment work is done and annual reports are made.

- The preparations were completed in order to be able to carry out the classified analyses in which 680 Level I and 52 Level II observation areas suitable for taking soil samples from the 850 observation sites that are set up to cover the forest areas were taken in 2015. The analyses will be finalized in 2019 and uploaded to the ICP Forests database.
- Needle-leaf measurements were taken at 52 Level II observation areas in 2015-2017. In 2019 the analyses will be completed and uploaded to the ICP Forests database. A third sampling was planned for 2019.
- In the 52 Level II observation areas, all the measurements for the first 5 years on the tree growth and the production were completed. Second 5-year measurements will be made in 2020.
- Intensive monitoring was planned for 18 of the 52 Level 2 observation sites and precipitation, deposition, litterfall, soil solution, phenological observations and air quality sampling were started to be studied. Analysis of deposition, soil solution and litterfall, phenological observations and air quality sampling results will be available in 2019 and uploaded to the ICP Forests database.
- The installation of an automatic meteorology observation station has been completed in 51 Level II observation areas and meteorological data has begun to be received. The results of meteorological stations will be uploaded to the ICP Forests database in 2019.
- Each year, 52 Levels II observation areas are monitored for ozone damage. No ozone damage was found.
- A laboratory was established in İzmir for the analysis of the samples taken from the observation areas in the Directorate of Aegean Forestry Research Institute. All requirements are completed, activated. In 2018, water and needle-leaf and rash ring tests were performed and passed.
- The collected data are stored in the national database and the reports are taken from the database.
- We contributed to the National Forest Inventory studies conducted by the Forest Administration and Planning Department.

Major results/highlights

- Ozone damage was encountered in the Level II observation areas of 18, 27, 28, 51, 53 within the scope of air quality monitoring made in 2017. In 2018, ozone loss was observed in the observation areas numbered 8, 10, 12, 18, 29, 30, 51, 52, 54.
- There are a total of 21,456 trees in 612 Level I and 52 Level II observation areas.
- Monitoring is done for 29 kinds of insects, fungi, viruses and so on.

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

Publications prepared within the scope of the programme:

Forest Ecosystems Monitoring Level I and Level II Programmes in Turkey. Prepared by: Ali TEMERİT, Umut ADIGÜZEL, Yücel FIRAT, H. Serdar KİP, Mehmet BİLGİ. National Focal Centre. ISBN: 978-975-8273-92-8

Health State of Forests in Turkey (2008-2012). Prepared by: Sıtkı ÖZTÜRK, Prof. Dr. Doğanay TOLUNAY, Ahmet KARAKAŞ, Dr. Celal TAŞDEMİR, Fatih AYTAR, Umut ADIGÜZEL, Mehmet Emin AKKAŞ. National Focal Centre. ISBN: 978-605-4610-44-0

Monitoring of forest ecosystems crown status evaluation photo catalog. Prepared by: Sıtkı ÖZTÜRK. National Focal Centre. ISBN: 978-605-393-038-9

Turkey Oaks Diagnosis and Diagnosis Guide. Prepared by: Sıtkı ÖZTÜRK. National Focal Centre. ISBN:978-975-8273-92-8

Some botanical characteristics of maple (*Acer*) species naturally occurring in Turkey. Prepared by: Sıtkı ÖZTÜRK. National Focal Centre, General Directorate of Forestry, Journal of Forestry Research. 2016/2 A Vol:1(4) ISSN: 2149-0783

Outlook

Future developments of the ICP Forest infrastructure

- In 2015-2018, litterfall, needle and leaf, deposition and soil solution working ringtest were entered and positive results were obtained. Analysis studies are continuing.
- The application for the soil working ringtest is expected in 2018.
- Samples sent from observation areas in the laboratory

  (a) 7000 unstructured soil samples, 14000 volume weight and skeleton analyses,

  (b) A total of 2531 age-dry weight analyses of 325 needle-leaf samples and 2206 rash samples were performed.

Planned research projects, expected results

- The health status report will be prepared in 2018 by using the results obtained.

- The sampling works for the deposition, soil solution, rash sample and phenological observations were started and samples were started to be procured.
- Tender for air quality sampling was made for the year 2018 and started with sampling with passive sampling method.
- Data from automatic meteorology observation stations installed at Level II observation sites will be reported at the end of 2019.

United Kingdom

National Focal Centre

Suzanne Benham, Forest Research

Main activities/developments

The Level II plot network has been maintained during 2018. Monitoring activities continue at 5 sites. Sample collections for deposition, soil solution, litterfall have been carried out. Monthly growth recording using permanent girth tapes continues. Meterological stations at the 5 sites have been replaced and upgraded to ensure continuous monitoring.

2018 began very cold with spring approximately two - three weeks late across the country and unusually heavy snow falls in March. These conditions resulted in late flushing of trees across the UK. From April onward rainfall was well below average with June and July completely dry resulting in less than 10% of expected summer rainfall. Sunny weather dominated the UK with temperature well above average and a period of 15 consequtive days saw temperatures exceed 30 °C. Early leaf senescence as a result of drought was observed across much of the southern UK.

The main research focus in the UK continues to be the threat to UK forests from pests and diseases and their impacts.

Major results/highlights

Completion of a knowledge review and assessment of the current evidence on oak health, identification of evidence gaps and prioritization of research needs within the UK.

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

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Outlook

Future developments of the ICP Forests infrastructure

- 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.
- Within current funding levels we have no plans to expand our monitoring activities.

Planned research projects, expected results

- 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
- The effects of the 2018 drought

ANNEX

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