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Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

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Progress in activities in 2020 and further development of effects-oriented activities

Effects of air pollution on forests

Progress report by the Programme Coordinating Centre of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests

Summary

The present report by the Programme Coordinating Centre of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) describes the outcomes of activities carried out since the previous report (ECE/EB.AIR/GE.1/2019/11–ECE/EB.AIR/WG.1/2019/4) and presents the outcomes of the thirty-sixth meeting of the ICP Forests Task Force (online, 11 and 12 June 2020). The activities were carried out and the report prepared in accordance with both the 2018–2019 and 2020–2021 workplans for the implementation of the Convention on Long-range Transboundary Air Pollution (respectively, ECE/EB.AIR/140/Add.1 and ECE/EB.AIR/144/Add.2) and in accordance with the revised mandate for the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (Executive Body decision 2019/16).[1]

In 64 permanent level II plots with continuous deposition monitoring since 1997, sea salt-corrected sulphate throughfall deposition dramatically decreased to as low as 30 per cent of the values found in the late 1990s. In the case of nitrogen compounds, the average reduction in throughfall deposition was also present, but much less marked. Based on the analysis of 259 ICP Forests level II and Swedish Throughfall Monitoring Network plots across Europe in 2018, regional patterns in throughfall deposition were again identified. High throughfall deposition of nitrate in kg of N per ha per year (> 8 kg N ha-1 y-1) was mainly found in Central and Western Europe (including Austria, Belgium, Czechia, Germany, Italy,

[1] Available at www.unece.org/env/lrtap/executivebody/eb_decision.html.

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Poland and Slovenia) while for ammonium higher throughfall deposition (> 8 kg N ha-1 y-1) was particularly found in southern Germany, northern Italy, Poland, western Slovakia and Switzerland.

The 2019 transnational crown condition survey showed that overall mean defoliation for all species was 23.3 per cent; there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2018. The damage assessment revealed that insects were again the predominant cause of damage and responsible for 26.4 per cent of all recorded damage symptoms, while abiotic agents were the second major causal agent group, responsible for 17.6 per cent of all damage symptoms.

I. Introduction

1. The present report of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is submitted for consideration by the Working Group on Effects in accordance with both the 2018–2019 and 2020-2021 workplans for the implementation of the Convention on Long-range Transboundary Air Pollution (respectively, ECE/EB.AIR/140/Add.1 and ECE/EB.AIR/144/Add.2) and in accordance with the revised mandate for the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (Executive Body decision 2019/16).

2. Germany is the lead country of ICP Forests, the Programme Coordinating Centre of which is hosted by the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries) under the Federal Ministry of Food and Agriculture. A total of 42 Parties to the Convention participate in ICP Forests activities.

3. The Ninth ICP Forests Scientific Conference, "Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change" (planned for the period 8 to 10 June 2020, in Zurich, Switzerland) was postponed due to the coronavirus disease (COVID-19) pandemic.[2] The thirty-sixth Task Force Meeting of ICP Forests was successfully held online on 11 and 12 June 2020.

II. Outcomes and deliverables during the reporting period

4. During the reporting period, ICP Forests produced or contributed to the following publications and reports:

(a) The 2019 joint progress report on policy-relevant scientific findings of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects (ECE/EB.AIR/GE.1/2019/3–ECE/EB.AIR/WG.1/2019/3). The report contains information on the data gathered and recorded by ICP Forests in 13 domains covering the most relevant aspects of forest ecosystems in Europe;

(b) The 2019 progress report of the Programme Coordinating Centre of ICP Forests to the EMEP Steering Body and the Working Group on Effects (ECE/EB.AIR/GE.1/2019/11–ECE/EB.AIR/WG.1/2019/4);

(c) The 2020 Technical Report of ICP Forests,[3] including thematic papers on:

(i) Atmospheric deposition in European forests in 2018;

(ii) Tree crown condition in 2019;

(iii) Results from the online questionnaire on the future of the intensive forest monitoring on level II plots under ICP Forests.

5. A total of 58 scientific papers based on ICP Forests data and with significant use of its infrastructure were published in international peer-reviewed journals in 2019. These publications cover the following fields: atmospheric deposition (10 articles); nutrient cycling (8 articles); ozone impacts (3 articles); heavy metals (3 articles); soil acidification, soil carbon and soil water (7 articles); tree and forest condition (4 articles); tree physiology, phenology, fructification, tree growth and mortality (8 articles); forest biodiversity and deadwood (9 articles); climate effects (5 articles); other (1 article). Moreover, four book chapters were published in 2019 based on ICP Forests data.

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[2] See http://icp-forests.net/events/event/listByType?type=scientific&page_q=AAAAOQAAAAE=&page=-1.

[3] Michel A, Prescher A-K, Schwärzel K, eds., "Forest Condition in Europe: 2020 Technical Report of ICP Forests. Report under the UNECE Convention on Long-range Transboundary Air Pollution". Forthcoming.

6. The ICP Forests Manual was revised and its new version adopted at the thirty-sixth Task Force Meeting.

III. Expected outcomes and deliverables for the next reporting period and in the longer term

7. In the second half of 2020 and in 2021, ICP Forests will carry out the following activities, in accordance with the 2020–2021 work plan for the Convention and with the decisions taken at the thirty-sixth meeting of the Task Force:

(a) Further acquisition of data on the condition and development of forest ecosystems and efforts to improve data quality and the data management system;

(b) Contribution to the 2020 joint progress report on policy-relevant scientific findings of the of the Steering Body to the EMEP and the Working Group on Effects (ECE/EB.AIR/GE.1/2020/3–ECE/EB.AIR/WG.1/2020/3);

(c) Finalization of the draft 2020 Technical Report of ICP Forests;

(d) Publication of ICP Forests Brief No. 4: Increased evidence of nutrient imbalances in forest trees across Europe;

(e) Development of ICP Forests Brief No. 5: Long-term defoliation trends;

(f) Report on the evaluation of heavy metals in forest floors and topsoils of ICP Forests level I plots.

IV. Cooperation with other groups, task forces and subsidiary bodies, including with regard to synergies and possible joint activities

8. A joint meeting of ICP Forests, the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) and the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends was held at the German Environment Agency headquarters in Dessau on 2 December 2019. The informal meeting of nine participants was arranged to discuss the initiative of the Coordination Centre for Effects to review the empirical critical loads of nitrogen. Both ICP Forests and ICP Vegetation expressed their intention to include their expertise in this process. Subsequently, the Programme Coordination Centre of ICP Forests contacted experts of its community to promote participation.

V. Strengthening the involvement of countries of Eastern and South-Eastern Europe, the Caucasus and Central Asia

9. Most of the countries of South-Eastern Europe and Turkey are included in the extensive ICP Forests level I monitoring of forest ecosystems. The more complex and intensive level II monitoring is carried out at only a few sites in South-Eastern Europe. None of the countries of the Caucasus or Central Asia is active in ICP Forests monitoring activities.

VI. Scientific and technical cooperation with relevant international bodies

10. By July 2019, under the National Emission Ceiling Directive,[4] the European Union member States were obliged to report the data for monitoring air pollution impacts. ICP

[4] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on

Forests protocols were used by about 50 per cent of the sites reporting parameters of annex V to the Directive.

11. ICP Forests took part in the second meeting of the European Environment Information and Observation National Reference Centres Forests (Copenhagen, 16 and 17 October 2019). The meeting provided an update on the development of the Forest Information System for Europe to support policies aimed at the protection and the sustainable and multifunctional use of forests in Europe, and discussed the development of the European Environment Agency forest road map, and how to best facilitate the post-2020 planning and communication of forest-related activities between the European Environment Agency, the European Environment Information and Observation Network and its stakeholders.

12. A joint ICP Forests/Acid Deposition Monitoring Network in East Asia “Workshop on regional impact assessment of atmospheric deposition and air pollution on forest ecosystems” was held in Niigata, Japan, from 18 to 22 November 2019. The workshop was held to:

(a) Exchange information on the current condition of atmospheric deposition/air pollution;

(b) Exchange information on the regional impact assessment of atmospheric deposition/ air pollution on forest ecosystems; and

(c) Discuss the possibility of scientific cooperation between ICP Forests and the Acid Deposition Monitoring Network in East Asia.

VII. Highlights of the scientific findings: policy-relevant issues

13. Examples of the highlights of 58 publications using ICP Forests data or the ICP Forests infrastructure in peer-reviewed journals in 2019 include the following results and conclusions:

(a) Both observational and experimental studies on European forest ecosystem responses to decreasing nitrogen deposition reviewed by Schmitz and others (2019)[5] reported more pronounced reactions of soil solution and foliar element concentrations than of understory vegetation, tree growth, or vitality, with the latter three showing no large-scale responses;

(b) In a case study in a remote broadleaved forest in Greece, the mean residence time of lead (Pb) in the forest floor was modelled to be 94 years, however, with a very high variation in years (Michopoulos and others, 2019).[6] This was due to highly variable Pb concentrations in deposition and litterfall during the study period of three years. It was confirmed that the highest Pb concentration among all parts of the ecosystem is in the organic soil horizon);

(c) Based on monitoring records from 276 Swiss plots from 1898 to 2013, an average annual tree mortality rate of 1.5 per cent was found (Etzold and others, 2019).[7] Gradually changing stand parameters (stand basal area and stand age) showed the strongest impact on tree mortality, modulated by climate; which had increasing importance during the last decades. The highly variable effects of recent climatic changes depended on the tree species in combination with abiotic and biotic stand and site conditions, suggesting that forest species composition and tree species ranges may change under future climate conditions;

the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, *Official Journal of the European Union*, L 344 (2016), pp. 1–31.

5 See Schmitz A. and others, “Responses of forest ecosystems in Europe to decreasing nitrogen deposition”, *Environmental Pollution*, vol. 244 (January 2019), pp. 980–994.

6 See Michopoulos P. and others, “Distribution and quantification of Pb in an evergreen broadleaved forest in three hydrological years”, *Journal of Forest Research* (2019).

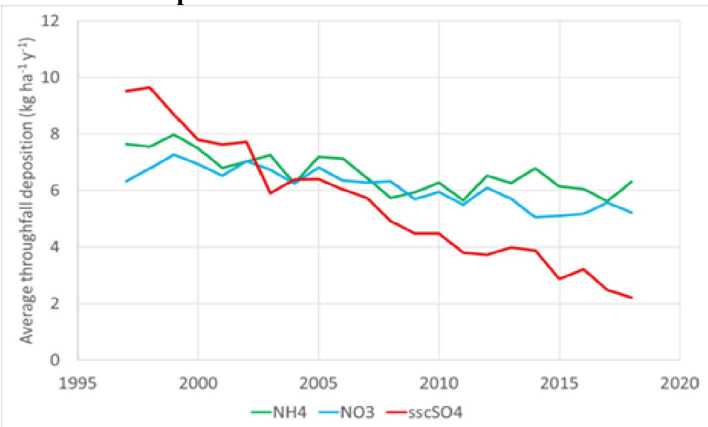
7 See Etzold S. and others, “One century of forest monitoring data in Switzerland reveals species- and site-specific trends of climate-induced tree mortality”, *Frontiers in Plant Science* (March 2019).

(d) In Italian forests of three biogeographic regions, temperature-related factors as well as soil nitrogen and phosphorous availability were the climatic and edaphic explanatory variables most correlated to plant trait variation in forest understories. It is suggested to consider soil properties as local drivers of trait variation in broad-scale functional biogeography studies of these systems (Chelli and others, 2019).[8]

14. The 2020 Technical Report and upcoming ICP Forests Brief No. 4 present results from 31 of the 42 countries participating in ICP Forests. Highlights of these results will be briefly discussed in the following subparagraphs:

(a) Since 1997, deposition monitoring has been running continuously in 64 permanent level II plots within the ICP Forests programme. During this period, the application of the protocols of the Convention and economic transformation led to a marked decrease of sulphur dioxide emissions in Europe (European Environment Agency, 2016).[9] As a consequence, sea salt- corrected sulphate throughfall deposition dramatically decreased in the considered period (see figure I below), reaching values as low as 30 per cent of those found in the late 1990s, and causing a similar decrease of deposition acidity.[10] In the case of nitrogen compounds, the average reduction in throughfall deposition was also present, but much less marked. It must be noted that total deposition of nitrogen is typically a factor 1 to 2 higher than throughfall deposition, due to canopy exchange processes;

Figure I
Trend in throughfall deposition of ammonium-nitrogen (green), nitrate-nitrogen (blue), and sea salt-corrected sulphate-sulphur (red) (kg ha^{-1} yr^{-1}) measured between 1997 and 2018 in 64 ICP Forests level II plots.



(b) In 2018, acidifying, buffering, and eutrophying compounds of open field bulk and below canopy throughfall deposition were analysed from 259 permanent plots and following the ICP Forests Manual, in both the European ICP Forests network and the Swedish Throughfall Monitoring Network:

(i) The uneven distribution of emission sources and receptors and the complex orography of parts of Europe results in a marked spatial variability of atmospheric deposition with regional patterns on a broader scale (see figure II below). In the case of nitrate, high and moderate throughfall deposition was mainly found in Central and Western Europe, including Austria, Belgium, Czechia, Germany, Italy, Poland and Slovenia (See figure II below). The Central and Western European area of high and moderate ammonium throughfall deposition is larger than for nitrate, with higher

[8] See Chelli S. and others, "Effects of climate, soil, forest structure and land use on the functional composition of the understorey in Italian forests", *Journal of Vegetation Science*, vol. 30, No. 6 (November 2019), pp. 1110–1121.

[9] See www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-convention-on-long-range-transboundary-air-pollution-lrtap-convention-10.

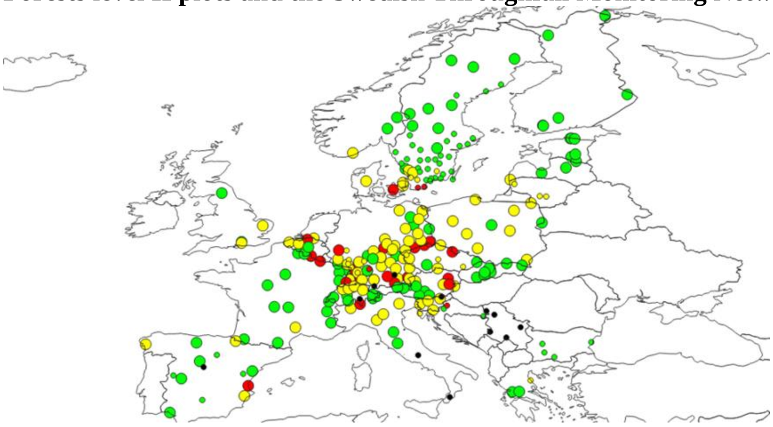
[10] Waldner P. and others, "Detection of temporal trends in atmospheric deposition of inorganic nitrogen and sulphate to forests in Europe", *Atmospheric Environment*, vol. 95 (October 2014), pp. 363–374.

throughfall deposition values particularly in southern Germany, northern Italy, Poland, western Slovakia and Switzerland (see figure III below);

(ii) Nitrogen compounds have two effects on the ecosystems: they are important plant nutrients with strong effects on plant metabolism, all forest processes and biodiversity, but they can also reinforce soil acidification.

Figure II

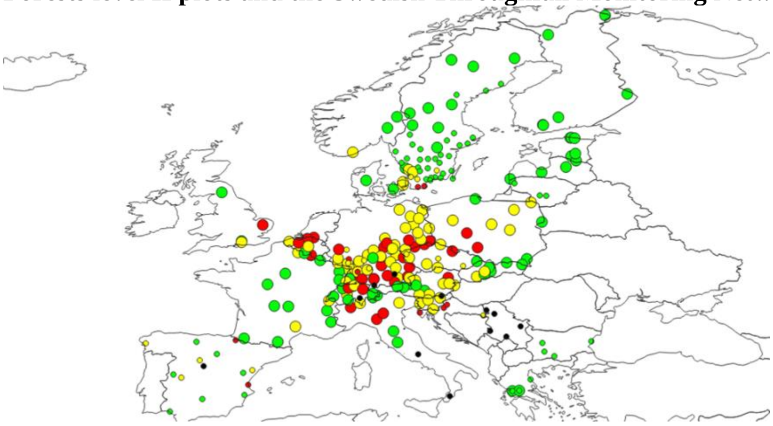
Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests level II plots and the Swedish Throughfall Monitoring Network.



Notes: Large points: validated data. Small points: not validated data. Black points: monitoring period shorter than 330 days. Legend: green (low) (0.0–4.0 kg NO3--N ha-1 yr-1), yellow (moderate) (>4.0–8.0 kg NO3--N ha-1 yr-1), red (high) (>8.0 kg NO3--N ha-1 yr-1). Preliminary maps: Map will be redrawn.

Figure III

Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests level II plots and the Swedish Throughfall Monitoring Network.



Notes: Large points: validated data. Small points: not validated data. Black points: monitoring period shorter than 330 days. Legend: green (low) (0.0–4.0 kg NH_4^+-N ha^{-1} yr^{-1}), yellow (medium) (>4.0–8.0 kg NH_4^+-N ha^{-1} yr^{-1}), red (high) (>8.0 kg NH_4^+-N ha^{-1} yr^{-1}). Map will be redrawn.

(c) Tree crown defoliation and occurrences of biotic and abiotic damage are important indicators of forest condition. As such, they are considered within 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) to provide information for sustainable forest management in Europe:[11]

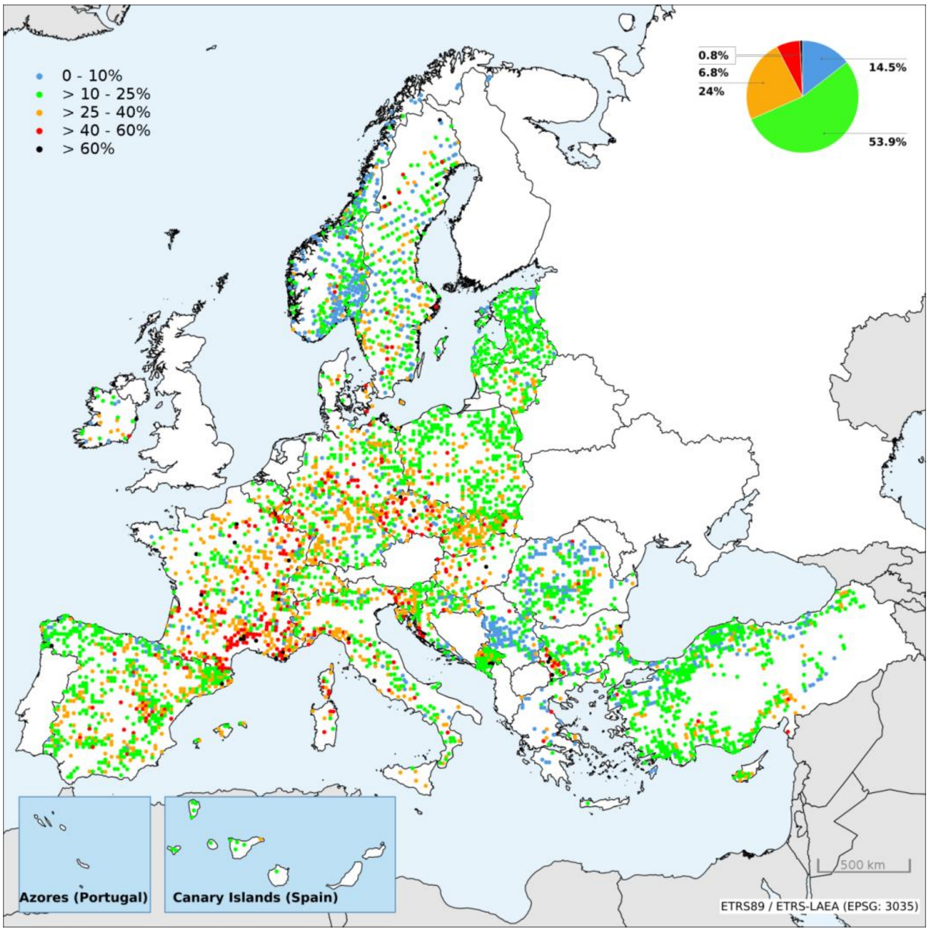
(i) The transnational crown condition survey in 2019 was conducted on 109,659 trees on 5,798 plots in 27 countries. Out of those, 103,831 trees were assessed in the field for defoliation. The overall mean defoliation for all species was 23.3 per cent in

[11] See www.foresteurope.org/docs/MC/MC_lisbon_resolution_annex1.pdf.

2019; there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2018. Broadleaved trees showed a higher mean defoliation than coniferous trees (23.2 per cent versus 22.2 per cent);

(ii) Mean defoliation of all species at plot level in 2019 is shown in figure IV below. More than two thirds (68.4 per cent) of all plots had a mean defoliation up to 25 per cent, and only 0.8 per cent of the plots showed severe defoliation (more than 60 per cent). Plots with mean defoliation of over 40 per cent were primarily located from the Pyrenees through southeast (Mediterranean) France to northwest Italy, but also from central and northern France through Germany and into Czechia, Slovakia, Hungary and western Bulgaria. Plots with low mean defoliation were found across Europe, but mainly in Norway, Sweden, Estonia, Romania, central Serbia, Greece and Turkey.

Figure IV
Mean plot defoliation of all species in 2019



Notes: The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class. Dead trees are not included.

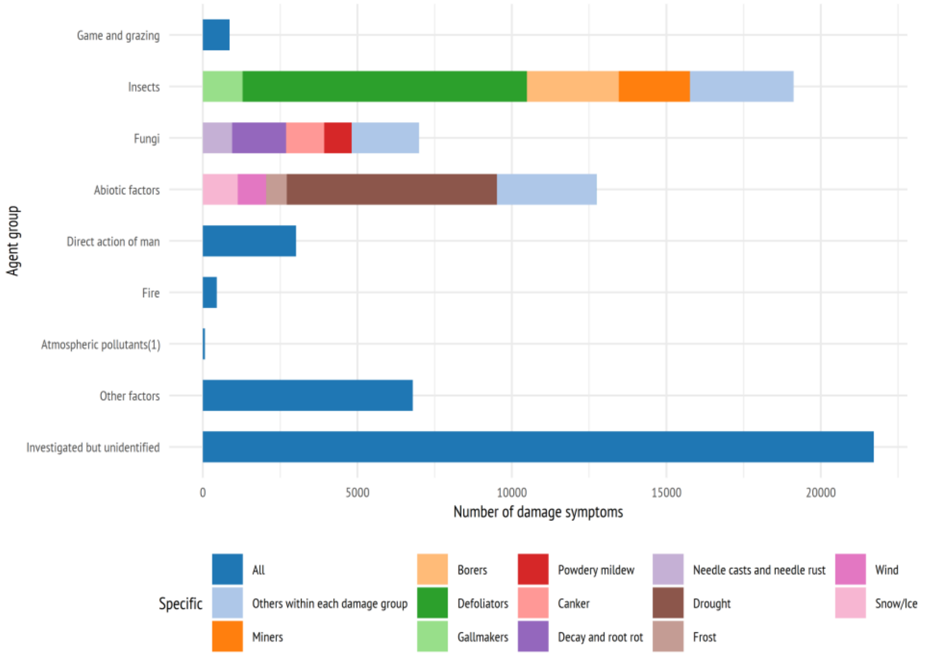
(d) Combining the assessment of damage symptoms and their biotic and abiotic causes with observations of defoliation allows for a better insight into the condition of trees, and the interpretation of the state of European forests and its trends in time and space is made easier:

(i) In 2019, damage cause assessments were carried out on 103,297 trees in 5,654 level I plots and 26 countries. On 50,446 trees (48.8 per cent) at least one symptom of damage was found. In total, 72,511 observations of damage were recorded with potentially multiple damage symptoms per tree. Both fresh and old damage was reported. On 1,153 plots no damage was found on any tree;

(ii) Figure V below shows that insects were the predominant cause of damage and responsible for 26.4 per cent of all recorded damage symptoms on level I plots across Europe. Abiotic agents were the second major causal agent group responsible for 17.6 per cent of all damage symptoms and fungi were the third, with 10.7 per cent of all damage symptoms.

Figure V

Number of damage symptoms according to agent groups and specific agents/factors



Notes: Multiple damage symptoms per tree were possible, and dead trees are included (n=67 666). (1) Visible symptoms of direct atmospheric pollution impact only.

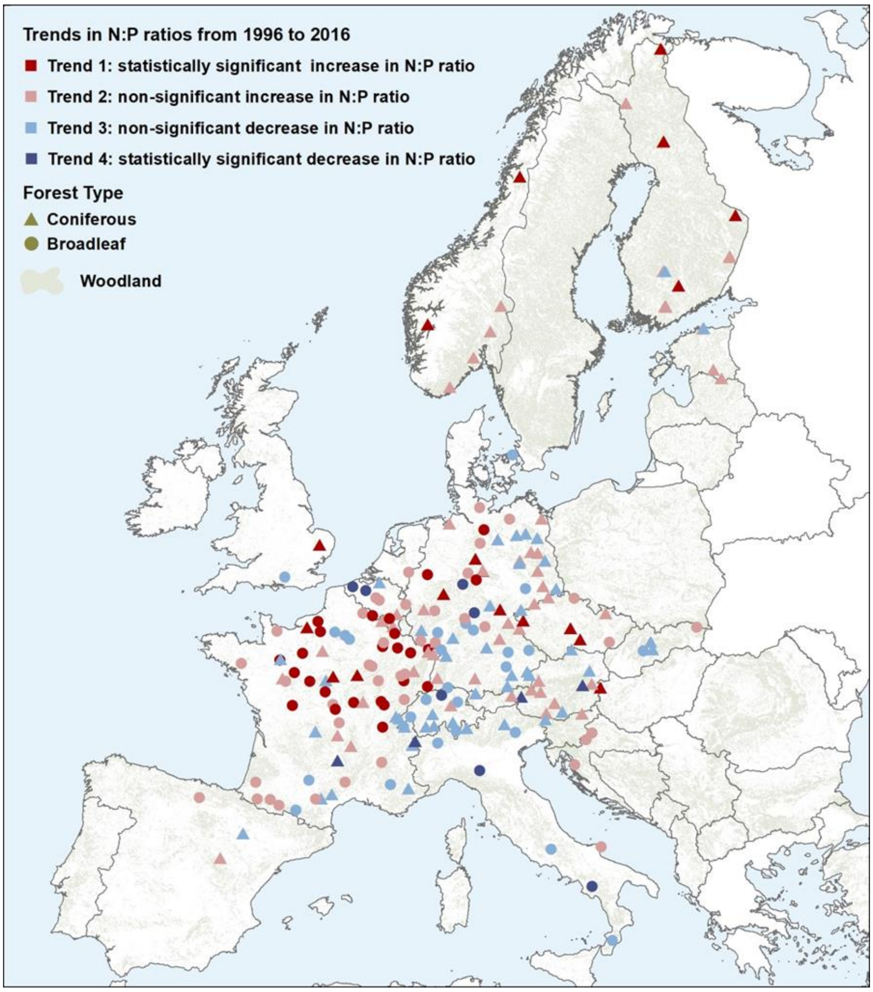
(e) Nutrient levels in tree foliage reflect atmospheric and soil-related influences and are an important component of the ICP Forests monitoring scheme under the Convention. Foliar nutrient analyses have been undertaken at least once on 1,061 level II intensive forest monitoring sites in 31 countries since the 1990s. These data allow detailed analyses of interactions between nutrients, the detection of trends over time, and the study of tree responses to environmental change:

(i) The data analysis revealed that deteriorated tree nutrition is present on 30 per cent of the investigated intensive forest monitoring sites across Europe. The rate of decrease in foliar phosphorous (P) is more than double that for foliar nitrogen (N), resulting in a shift towards higher N:P ratios. Although certain sites show a trend towards lower N:P ratios, the number of sites with N:P ratios above corresponding, species-specific limit values has increased for both broadleaf and coniferous forests, indicating increasingly imbalanced tree nutrition across Europe (see figure VI below);

(ii) Shifts in the ratio between levels of foliar N and foliar P can be attributed to human emissions of N and carbon. The resulting nutrient imbalance has the potential to limit tree growth, leading to a reduction in wood supply and carbon sequestration by forests, and to decrease the resistance and resilience of forest trees to stressors such as drought or insect infestations;

(iii) The implications for forest productivity and for the potential of forest ecosystems to respond to global environmental change underline the importance of monitoring the deposition of N and other elements into forests and their subsequent impacts on the structure and functioning of forest ecosystems. Counteracting nutrient imbalances in forest trees through P fertilization of forest soils is not generally considered viable or cost-effective in forests. Rather the nutrient imbalances detected on the ICP Forests monitoring plots present a strong argument for further reducing the levels of air pollutants, both for ecological reasons as well as for economic benefits.

Figure VI
Trends over time in foliar N:P ratios for coniferous trees (Scots pine, Norway spruce) and broadleaf trees (European beech, temperate oaks) at ICP Forests intensive monitoring sites across Europe from 1996 to 2016



VIII. Publications

15. For a full list of all 58 ICP Forests publications using ICP Forests data or the ICP Forests infrastructure in peer-reviewed journals and references for the present report, please refer to the 2020 ICP Forests Technical Report or visit the ICP Forests website.[12]

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