ICP FORESTS

2020

Forest Condition in Europe

The 2020 Assessment

ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention)

LRTAP Long-range Transboundary Air Pollution

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

THÜNEN

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). 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 2020 Technical Report presents results from 31 of the 42 countries participating in ICP Forests. Part A presents research highlights from the January–December 2019 reporting period, including:

- a review of 62 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure were used;
- a list of the presentations at the 8th ICP Forests Scientific Conference in Ankara, 11–13 June 2019;
- a list of all 47 research projects using ICP Forests data/infrastructure and ongoing for at least one month between January and December 2019.

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 2018;
- tree crown condition in 2019;
- results from the online questionnaire on challenges associated with long-term forest ecosystem monitoring on ICP Forests Level II plots over time.

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

Online supplementary material complementing Part B 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].

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

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

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

Chapter 5 presents results of atmospheric throughfall deposition of acidifying, buffering, and eutrophying compounds in 2018 in 293 ICP Forests Level II permanent forest monitoring plots in both the European ICP Forests network and the Swedish Throughfall Monitoring Network (SWETHRO).

High values of nitrate deposition were mainly found in central Europe (Germany, Denmark, Belgium and eastern Austria), while for ammonium they were also found in northern Italy and Poland. The area of high deposition is smaller for sulphate, including some plots in Germany, Greece and Poland. High sulphate values are also measured in Belgium, but they are partially due to deposition of marine aerosol, and they are less evident after sea-salt correction.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in eastern Europe. The correction for the marine contribution of calcium matters mainly for sites in central Europe and in Spain. 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 ammonium) or lower (typically for buffering compounds) than the throughfall deposition, due to canopy exchange processes.

Chapter 6 on tree crown condition in 2019 presents results from crown condition assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2019, as well as long-term trends for the main tree species and species groups.

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% in 2019, and there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2018. Broadleaved trees showed a slightly higher mean defoliation than coniferous trees (23.2% vs. 22.2%). Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (28.6% and 26.9%, respectively). Common beech had the lowest mean defoliation (21.0%) followed by deciduous (sub-) Mediterranean oaks with 21.2% and Norway spruce with 22.0%. Mediterranean lowland pines had the highest percentage (75.8%) of trees with

⩽ 25% defoliation, while deciduous temperate oaks had the lowest (58.3%).

In 2019, damage cause assessments were carried out on 103 297 trees on 5 654 plots in 26 countries. On 50 446 trees (48.8%) at least one symptom of damage was found. On 1 153 plots no damage was found on any tree.

Insects were the predominant cause of damage and responsible for 26.4% of all recorded damage symptoms. Almost half of the symptoms caused by insects were attributed to defoliators (48.1%), the most frequent of all specified damage causes.

Abiotic agents were the second major causal agent group responsible for 17.6% of all damage symptoms. Within this agent group, more than half of the symptoms (53.4%) were attributed to drought, while snow and ice caused 8.9%, wind 7.2%, and frost 3.8% of the symptoms.

Chapter 7 describes practical challenges associated with long-term forest monitoring. ICP Forests has been a pioneering and successful initiative in transnational long-term forest ecosystem monitoring under the UNECE Air Convention since its establishment in 1985. Its design based on permanent monitoring plots has allowed the study of responses of forest ecosystems to environmental changes and to detect significant temporal and spatial trends. With time, however, the intensive (Level II) forest monitoring plots have started to face several practical challenges, and it has become widely acknowledged within the monitoring community that these need to be addressed to ensure a successful continuation of the programme. As the monitoring plots were installed in adult forest stands, many of the investigated stands are now old and will be regenerated within the next few decades. This will have a strong impact on the plots and the condition of the investigated ecosystems, and it may even impair the continuation of some survey types.

A questionnaire was prepared and distributed to the National Focal Centres (NFCs), which represent the ICP Forests member countries, with the aim to receive feedback and discuss expectations and recommendations for action. Chapter 7 presents the questionnaire's main results from a total of 35 respondents (30 countries and five German forest research institutes representing eight German Bundesländer) between 9 May and 25 June 2019.

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Online supplementary material complementing Chapter 6 and Chapter 7 is available at
http://icp-forests.net/page/icp-forests-technical-report

FOREWORD

Dear Reader,

It is my pleasure to introduce you to the newly designed ICP Forests Technical Report "Forest Condition in Europe – The 2020 Assessment". Whoever you are - a scientist, a forest manager, a policy maker, or a citizen with no specific professional interest in forest-related matters - if you get to read this report then you share our concern about the status of our forests.

Here you will read about the recent status and 20-year time development of tree health and vitality in our forests, from Scandinavia to Italy, and from Turkey to Spain. You will learn about quality and quantity of nutrients and pollutants deposited annually in our most common and important forest ecosystems via atmospheric precipitation. And you will see the extent of scientific initiatives, the demand for data, the ongoing research projects, the activity Country by Country, and the technical challenges that long-term monitoring places to forest managers and scientists.

ICP Forests is not perfect and since 1985 we strive for collecting comparable data and information on the condition of forests in the UNECE region. Yet, ICP Forests is unique in Europe and perhaps in the World: when reading this report you will figure out the huge effort necessary to keep the programme moving on the long-term and at the large-scale: thousands of plots distributed across Europe and beyond, and hundreds of scientists, field surveyors, lab technicians, administrative staff fully engaged to co-operate, collect, validate, interpret, and report data according to shared methodologies.

In a time when environmental challenges and threats to our forests have a global dimension, it is worth considering that ICP Forests is part of the UNECE Air Convention, the oldest multi-national and multi-lateral environmental agreement in the World, and – at the time it was launched in 1979 – a visionary approach for protecting our forests and our environment. In this context, the role of ICP Forests today is even more important, with climate change interacting with air pollution and triggering the role of other more traditional adverse factors across diverse spatial, temporal and ecological scales.

As Chairman of the Programme I would like to express here my gratitude and encouragement to the Air Convention bodies, the Lead Country, all the participating Countries, Groups, Panels and Committees of the ICP Forests for their support with financial, human and intellectual resources.

Hope you will enjoy reading this report as much as I did.

Marco Ferretti
Chairman of the ICP Forests
Swiss Federal Research Institute WSL

Forests provide many benefits including fresh air, clean water, natural carbon storage, timber, food and other products. They are also home to many species and natural environments.

Forests, which are indispensable for life, are the heart of the Earth with its characteristics such as prevention of erosion and pollution, contributing to formation of groundwater and natural water sources for animals, and producing oxygen.

I feel honored to present the 2019 Technical Report of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) on forests providing many benefits.

Turkey supports the ICP Forests programme and the studies carried out in the frame of the programme. We were very glad to host the 35th Task Group Meeting and the 8th Scientific Conference held in Ankara on 11-14 June 2019 and to contribute to the ICP Forests programme.

Over a fourth of Turkey, i.e. 27.6% of the country (22.7 million ha) is covered with forests and it takes first place in Europe in terms of species diversity. Within the scope of the ICP Forests programme, 67 species are monitored on Level I and Level II plots. Our country is very rich in terms of biological diversity and contains approximately 11 500 plant species.

In order to increase and improve forest areas, afforestation, rehabilitation and erosion works are carried out every year on 100 000 ha. Forest area has increased since 1960 by 1 500 000 ha.

The principles of sustainable forest management (with six criteria and 39 indicators) are followed in our forests (economic, ecological and social) and are important for our society.

Forest protection is important for all forest related stakeholders, and the amount of damaged forest areas is probably one of the most important indicators for forests, with forest damage agents being more or less the same over the years. However, developments are not always so predictable and we are still facing new challenges. We can share our experience.

Experts have found a new disease for Turkey named chestnut gal bee *Dryocosmus kuriphilus*, pine pest *Leptoglossus occidentalis,* and they have determined the damages and invasion that they brought to our forests.

There is a need for co-operation in the presence of the concerned experts in the frame of the ICP Forests programme and Turkey stands by it.

I would like to thank everyone who participated in the ICP Forests programme for their efforts and wish further success.

Bekir KARACABEY
Ministry of Agriculture and Forestry
General Director of Forestry
Republic of Turkey

Participants at the 8th Scientific Conference and/or 35th Task Force Meeting of ICP Forests in Ankara, 11–14 June 2019, representing 21 countries

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 seven subsidiary groups (six ICPs and a joint Task Force with WHO) that report to the Working Group on Effects (WGE) under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention[1]) on the effects of air pollution and other stressors 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 5852 observation plots (as at 2019) 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 623 plots (as at 2018, 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[2] 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 recent years, forest monitoring has proven to be more relevant than 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.

This 2020 Technical Report of ICP Forests, its online supplementary material, and other information on the programme can be downloaded from the ICP Forests website[3].

Programme highlights in 2019

People

- Kai Schwärzel from the German Thünen Institute of Forest Ecosystems took office as new Head of the ICP Forests Programme Co-ordinating Centre in March 2019 after Walter Seidling's retirement from this position in October 2018. We are very grateful for Walter's efforts and dedication as PCC Head for the last six years and welcome Kai to the ICP Forests community.
- The Task Force welcomed Diana Pitar from the Romanian National Institute for Research and Development in Forestry "Marin Drăcea" (INCDS) as new chair of the Expert Panel on Ambient Air Quality (EP AAQ) during the Task Force Meeting in Ankara, 13–14 June 2019; Elena Gottardini remains co-chair. The former EP AAQ chair Marcus Schaub from the Swiss Federal Research Institute WSL had successfully led the EP since 2004 and he will remain chair of the Scientific Committee of ICP Forests.

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:
  - "Data Availabilty Reports" which describe the current data bases in aggregated overviews to identify gaps and inconsistencies,
  - continued revision of the data model (data base structure) to harmonize data series,
  - a new "checkout module" of the data portal to simplify data corrections and resubmissions.

Outreach and reporting

- First data from ICP Forests plots following the methodologies agreed upon by the UNECE Air Convention have been delivered by the EU Member States to the European Environment Agency (EEA) to meet the reporting requirements for main air pollutants and their effects under the new EU National Emission Ceiling (NEC) Directive[4].
- ICP Forests co-organized a session at the XXV IUFRO World Congress 2019 in Curitiba, Brazil, 29 Sept – 5 Oct 2019, and gave an invited presentation about tree mortality in the relevant session at the same conference. The ICP Forests session titled "Long-Term Forest Monitoring Networks for Evaluating Responses to Environmental Change" was organized by the chairs of the ICP Forests

[1] https://www.unece.org/env/lrtap/welcome.html.html

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

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

[4] https://www.eea.europa.eu/themes/air/air-pollution-sources-1/national-emission-ceilings

Scientific Committee Marcus Schaub and Lars Vesterdal, Hiroyuki Sase (EANET), and Marco Ferretti (Chairman of the ICP Forests). From 22 presentations covering a wide range of topics, 11 were given from ICP Forests participants.

- The results from the Working Group on Quality Assurance and Quality Control on the 21th Needle/leaf Interlaboratory Comparison Test 2018/2019 and the 9th Deposition and Soil Solution Working Ringtest 2019 were published as were the results from the EP Crown Condition and Damage Causes on the International Cross-Comparison Course for Central and Northern Europe 2019 and European Photo International Cross-Comparison Course (Photo ICC) 2019. All of these reports can be downloaded from the ICP Forests website[1].
- The number of reported international, peer-reviewed publications using data that had either originated from the ICP Forests database or from ICP Forests plots rose from 34 in 2018 to 62 in 2019[2], thereby proving a constantly increasing relevance and use of the ICP Forests data and infrastructure in various research areas such as atmospheric deposition, ozone, heavy metals, nutrient cycling, climate, soil carbon and soil water, tree and forest condition, tree physiology, tree growth and mortality, forest biodiversity and deadwood.

Programme meetings

- The EMEP Steering Body and Working Group on Effects under the UNECE Air Convention met in Laxenburg, Austria, 19–21 March 2019, and in Geneva, 9–13 September 2019[3], to discuss the progress in activities and further development of effects-oriented activities e.g. the new 2020-2021 workplan for the implementation of the Convention.
- The Expert Panels on Crown Condition and Damage Causes, Soil and Soil Solution, Foliage and Litterfall, Deposition and QA/QC in Laboratories met in Brussels, 25–29 March 2019, to discuss the current status and future developments of the programme in the different surveys.
- A joint ICP Vegetation and ICP Forests Expert Workshop was held in Switzerland, 12 April 2019, to discuss further co-operation and advance knowledge about ozone effects on forests within the Air Convention.
- The International Cross-comparison Course Crown Condition (Central and Northern Europe) was held in Chorin, Germany, on 3–6 June 2019.
- The 8th ICP Forests Scientific Conference *Trends and events - Drought, extreme climate and air pollution in European forests* took place in Ankara, 11–13 June 2019, with 61 participants from 21 countries, together with the directly following Task Force Meeting.
- The 35th ICP Forests Task Force Meeting was hosted by the General Directorate of Forestry and the Ministry of Agriculture and Forest of the Republic of Turkey in Ankara, 13–14 June 2019, with 43 participants from 21 countries.
- The 7th Heads of the Laboratories Meeting took place in Braşov, Romania, 5–6 September 2019, with the aim to discuss e.g. the latest foliage and litterfall, deposition and soil solution ringtest results and other QA/QC issues relevant in ICP Forests.
- The Programme Co-ordinating Group (PCG) and Scientific Committee met in Berlin, 12–13 November 2019, to discuss current issues and the ICP Forests' further progress.
- A joint EANET[4] and ICP Forests Expert Workshop was held on regional impact assessment of atmospheric deposition and air pollution on forest ecosystems, 18–22 November 2019, Niigata, Japan, with the objectives to exchange information on the current condition of atmospheric deposition/air pollution and its regional impact on forest ecosystems and to discuss further possibilities of scientific cooperation between ICP Forests and EANET.

Acknowledgements

We wish to thank the Federal Ministry of Food and Agriculture (BMEL) and all participating countries for the continued implementation and financial support of the ICP Forests. We also thank the United Nations Economic Commission for Europe (UNECE) and the Thünen Institute for the partial funding of the ICP Forests Programme Co-ordinating Centre.

Our sincere gratitude goes to Sıtkı Öztürk and his colleagues from the General Directorate of Forestry and the Ministry of Agriculture and Forest in Turkey for hosting the 8th Scientific Conference and 35th Task Force Meeting of ICP Forests in Ankara, 10–14 June 2019. We would like to also express our appreciation for valuable comments from the ICP Forests community on draft versions of this report.

For more than 35 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

[1] http://icp-forests.net/page/working-group-on-quality
http://icp-forests.net/page/icp-forests-other-publications
[2] http://icp-forests.net/page/publications
[3] https://www.unece.org/index.php?id=50345

[4] Acid Deposition Monitoring Network in East Asia. https://www.eanet.asia

Table 1-1: Overview of the number of Level II plots used in different surveys by the participating countries in 2018 as submitted to the ICP Forests database by 20 May 2020

	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						6	6			
Belgium	5	8	9					5	5	4		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				7		7	10		6	7
Denmark		4	4				3		4	4		3	4
Estonia		6	6						1	1			5
Finland		6	7				1			8			8
France		93	25				10		10	13		82	14
Germany	35	85	65	50	21	14	11	16	43	78	8	51	50
Greece		4	3						4	4	3	2	3
Hungary		6											
Italy		30	8										
Latvia	1	2	3						3				3
Lithuania	3	9	3						3	1	9	1	2
Norway		3	3										3
Poland	12	135	12										12
Romania	4						4	3	3	4		3	5
Serbia		5	5		5				5	5	5	5	3
Slovakia	3	8	7							6	4		4
Slovenia	9	10	4										4
Spain	14	14	14				14	14	14	14	14	14	5
Switzerland	7	17	14							18	9		9
Turkey		52											
UK			5				3		4	5			5
Total	**100**	**528**	**229**	**61**	**26**	**14**	**59**	**38**	**119**	**189**	**56**	**177**	**160**

PART A

ICP Forests-related research highlights

2

OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY – DECEMBER 2019)

Between January and December 2019, 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 beyond air pollution effects.

The following overview includes all 62 English online and in print publications from 2019 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].

Atmospheric deposition

Balestrini R, Delconte CA, Buffagni A, et al (2019) **Dynamic of nitrogen and dissolved organic carbon in an alpine forested catchment: atmospheric deposition and soil solution trends.** Nature Conservation 34:41–66. https://doi.org/10.3897/natureconservation.34.30738

Cecchini G, Andreetta A, Marchetto A, Carnicelli S (2019) **Atmospheric deposition control of soil acidification in central Italy.** CATENA 182:104102. https://doi.org/10.1016/j.catena.2019.104102

De Marco A, Proietti C, Anav A, et al (2019) **Impacts of air pollution on human and ecosystem health, and implications for the National Emission Ceilings Directive: Insights from Italy.** Environment International 125:320–333. https://doi.org/10.1016/j.envint.2019.01.064

Ferm M, Granat L, Engardt M, et al (2019) **Wet deposition of ammonium, nitrate and non-sea-salt sulphate in Sweden 1955 through 2017.** Atmospheric Environment: X 2:100015. https://doi.org/10.1016/j.aeaoa.2019.100015

Karlsson PE, Karlsson GP, Hellsten S, Akselsson C, Ferm M, Hultberg H (2019) **Total deposition of inorganic nitrogen to Norway spruce forests – Applying a surrogate surface method across a deposition gradient in Sweden.** Atmospheric Environment 217:116964. https://doi.org/10.1016/j.atmosenv.2019.116964

Kosonen Z, Schnyder E, Hiltbrunner E, et al (2019) **Current atmospheric nitrogen deposition still exceeds critical loads for sensitive, semi-natural ecosystems in Switzerland.** Atmospheric Environment 211:214–225. https://doi.org/10.1016/j.atmosenv.2019.05.005

Schmitz A, Sanders TGM, Bolte A, Bussotti F, Dirnböck T, Johnson J, Penuelas J, Pollastrini M, Prescher A-K, Sardans J, Verstraeten A, de Vries W (2019) **Responses of forest ecosystems in Europe to decreasing nitrogen deposition.** Environmental Pollution 244:980–994. https://doi.org/10.1016/j.envpol.2018.09.101

Salemaa M, Lindroos A-J, Merilä P, et al (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. https://doi.org/10.1016/j.scitotenv.2018.10.364

Thimonier A, Kosonen Z, Braun S, Rihm B, Schleppi P, Schmitt M, Seitler E, Waldner P, Thöni L (2019) **Total deposition of nitrogen in Swiss forests: Comparison of assessment methods and evaluation of changes over two decades.** Atmospheric Environment 198:335-350. https://doi.org/10.1016/j.atmosenv.2018.10.051

Jakovljević T, Marchetto A, Lovreškov L, et al (2019) **Assessment of atmospheric deposition and vitality indicators in Mediterranean forest ecosystems.** Sustainability 11:6805. https://doi.org/10.3390/su11236805

Nutrient cycling

Dhiedt E, De Keersmaeker L, Vandekerkhove K, Verheyen K (2019) **Effects of decomposing beech (*Fagus sylvatica*) logs on the chemistry of acidified sand and loam soils in two forest reserves in Flanders (northern Belgium).** Forest Ecology and Management 445:70–81. https://doi.org/10.1016/j.foreco.2019.05.006

Durante S, Augusto L, Achat DL, et al (2019) **Diagnosis of forest soil sensitivity to harvesting residues removal – A transfer study of soil science knowledge to forestry practitioners.** Ecological Indicators 104:512–523. https://doi.org/10.1016/j.ecolind.2019.05.035

Fanin N, Bezaud S, Sarneel JM, et al (2019) **Relative importance of climate, soil and plant functional traits during the early decomposition stage of standardized litter.** Ecosystems. https://doi.org/10.1007/s10021-019-00452-z

Flechard CR, Ibrom A, Skiba UM, et al (2019) **C/N interactions in European forests and semi-natural vegetation.** Part I: Fluxes and budgets of C, N and greenhouse gases from ecosystem monitoring and modelling. Biogeochemistry: Greenhouse Gases https://doi.org/10.5194/bg-2019-333

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

Fleck S, Eickenscheidt N, Ahrends B, Evers J, Grüneberg E, Ziche D, Höhle J, Schmitz A, Weis W, Schmidt-Walter P, Andreae H, Wellbrock N (2019) **Nitrogen status and dynamics in German forest soils.** In: Wellbrock N., Bolte A. (eds) Status and Dynamics of Forests in Germany. Ecological Studies (Analysis and Synthesis), Vol 237: 123-166. Springer, Cham. https://doi.org/ 10.1007/978-3-030-15734-0_5

Roulier M, Coppin F, Bueno M, et al (2019) **Iodine budget in forest soils: Influence of environmental conditions and soil physicochemical properties.** Chemosphere 224:20–28. https://doi.org/10.1016/j.chemosphere.2019.02.060

Vanguelova EI, Pitman RM (2019) **Nutrient and carbon cycling along nitrogen deposition gradients in broadleaf and conifer forest stands in the east of England.** Forest Ecology and Management 447:180–194. https://doi.org/10.1016/j.foreco.2019.05.040

Ozone

Araminienė V, Sicard P, Anav A, et al (2019) **Trends and inter-relationships of ground-level ozone metrics and forest health in Lithuania.** Science of The Total Environment 658:1265–1277. https://doi.org/10.1016/j.scitotenv.2018.12.092

Paoletti E, Alivernini A, Anav A, et al (2019) **Toward stomatal–flux-based forest protection against ozone: The MOTTLES approach.** Science of The Total Environment 691:516–527. https://doi.org/10.1016/j.scitotenv.2019.06.525

Hůnová I, Kurfürst P, Baláková L (2019) **Areas under high ozone and nitrogen loads are spatially disjunct in Czech forests.** Science of The Total Environment 656:567–575. https://doi.org/10.1016/j.scitotenv.2018.11.371

Heavy metals

Malinova D, Malinova L, Petrova K, Hristov B (2019) **Coefficients of heavy metal accumulation in forest soils.** Bulgarian Journal of Agricultural Science 25(3):519-526

Michopoulos P, Bourletsikas A, Kaoukis K, Kostakis M, Thomaidis NS, Passias II, Kaberi H, Iliakis S (2019) **Distribution and quantification of Pb in an evergreen broadleaved forest in three hydrological years.** Journal of Forest Research. https://doi.org/10.1007/s11676-019-01018-4

Stojnic S, Kebert M, Drekic M, Galic Z, Kesic L, Tepavac A, Orlovic S (2019) **Heavy metals content in foliar litter and branches of *Quercus petraea* (Matt.) Liebl. and *Quercus robur* L. observed at two ICP Forests monitoring plots**. South-east European Forestry 10(2):151-157. https://doi.org/ 10.15177/seefor.19-11

Climate effects

Bogdziewicz M, Szymkowiak J, Fernández-Martínez M, et al (2019) **The effects of local climate on the correlation between weather and seed production differ in two species with contrasting masting habit.** Agricultural and Forest Meteorology 268:109–115. https://doi.org/10.1016/j.agrformet.2019.01.016

Etzold S, Ziemińska K, Rohner B, Bottero A, Bose AK, Ruehr NK, Zingg A, Rigling A (2019) **One century of forest monitoring data in Switzerland reveals species- and site-specific trends of climate-induced tree mortality.** Frontiers in Plant Science 10. https://doi.org/10.3389/fpls.2019.00307

Paul C, Brandl S, Friedrich S, et al (2019) **Climate change and mixed forests: how do altered survival probabilities impact economically desirable species proportions of Norway spruce and European beech?** Annals of Forest Science 76. https://doi.org/10.1007/s13595-018-0793-8

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3 PRESENTATIONS AT THE 8TH SCIENTIFIC CONFERENCE, ANKARA, 11–13 JUNE 2019

The 8th ICP Forests Scientific Conference *Trends and events - Drought, extreme climate and air pollution in European forests* was hosted by the General Directorate of Forestry and the Ministry of Agriculture and Forest of the Republic of Turkey in Ankara, 11–13 June 2019, with 61 participants from 21 countries.

The scope of the 8th ICP Forests Scientific Conference had been inspired by the recent drought and other extreme events occurring across Europe in 2018. Its focus was on forest ecosystem effects from recent and past extreme events caused by drought, heat, storms, frost and flooding and from air pollution.

Three decades of monitoring effects of air pollution through ICP Forests has provided long-term data series which is a unique asset for the evaluation of status, trends, and processes in European forest ecosystems in a changing environment. With *Trends and events - Drought, extreme climate and air pollution in European forests* the aim was 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.

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 interested in long-term trends and extreme events in forests. Especially, researchers using ICP Forests data in their projects, evaluations, and modelling exercises were invited.

The following list includes all oral and poster presentations at the 8th ICP Forests Scientific Conference. All conference abstracts are available from the ICP Forests website[1].

Averill C, Dietze M, Crowther T, Bhatnagar J [Presentation]
Forecasting the forest mycorrhizas and soil carbon balance under future nitrogen deposition regimes

Babur E, Dindaroğlu T [Presentation]
Determination of seasonal changes effects on some physicochemical and microbial properties of the forest floor of even-aged black pine, Lebanon cedar and Oriental beech in karst ecosystems

Butorac L, Jakovljević T, Jelić G, Limić I, Seletković I, Potočić N, Lovreškov L, Indir K [Presentation]
Anti-erosion and hydrological role of the black pine forest under Mediterranean climate

Cailleret M, Haeni M, Schönbeck L, Gessler A, Schaub M [Presentation]
Dose-response relationships between ozone fluxes and tree radial growth across Europe - preliminary results

Calatayud V, Pilar Martín M, Migliavacca M, Carrara A [Poster]
The Majadas experimental site (Spain): An advanced platform for monitoring and research

Češljar G, Đorđević I, Brašanac-Bosanac L, Gagić-Serdar R, Eremija S, Hadrović S, Rakonjac L [Poster]
The impact of extreme climate factors on forest ecosystems in the Republic of Serbia in the period 2004–2018

Ciceu A, Leca S, Sidor C, Popa I, Chivulescu S, Pitar D, Badea O [Presentation]
Species adaptability to drought quantified by crown condition resilience components in Romanian Level I monitoring network

Dinca L, Onet A, Braga C, Crisan V, Teusdea A [Poster]
The influence of some risk abiotic factors (windfalls and droughts) on the characteristics of forest soils from Romania

Ferretti M, Baltensweiler A, Lanz A, Rohner B [Presentation]
The impact of 2018 drought on beech forests in Switzerland

Eray Hangül, Sıtkı Öztürk [Poster]
Phenological observation

Jakovljević T, Potočić N, Seletković I, Indir K, Butorac L, Jelić G, Zgrablić Ž, De Marco A, Marchetto A, Lovreškov L [Presentation]
Assessment of atmospheric deposition, foliar nutrition, defoliation and growth in Mediterranean forest ecosystems of Croatia

Jochheim H, Höhn A, Breuer J, Sommer M [Presentation]
Patterns of silicon cycling in a beech forest ecosystem in northeast Germany

Kuzmanova R [Poster]
The length of European beech (*Fagus sylvatica* L.) growing season in the Western Balkan Range

Lovreškov L, Jakovljević T, Potočić N, Seletković I, Butorac L, Indir K, Jelić G, Zgrablić Ž, Marchetto A, De Marco A [Poster]
Ozone impact on Mediterranean forest ecosystems of Croatia

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

Luttkus M, Wolke R, Bernd H, Tilgner A, Poulain L, Herrmann H [Poster]
The influence of two different land use datasets on air quality

Merilä P, Lindroos A-J [Poster]
Changes in carbon stocks of forest soil during 1995 – 2016 on the intensive monitoring plots of forest ecosystems in different parts of Finland

Merilä P, Salemaa M, Kieloaho A-J, Lindroos A-J, Poikolainen J, Manninen S [Presentation]
Nitrogen concentration of boreal mosses in relation to nitrogen forms of atmospheric deposition in background areas

Öztürk F, Yücel G, Ihsan Ilhan A, Balta T, Rasan G, Balcilar I, Tuncel G [Presentation]
Wet deposition of major ions to forest ecosystem at the eastern Mediterranean

Pascu I-S, Dobre A-C, Leca S, Badea O [Presentation]
Improvement of current phenological analysis techniques through the use of multitemporal TLS observations

Petrov Dimitrov D, Zhiyanski M [Poster]
European beech (*Fagus sylvatica* L.) xylem anomalies - explicit clue for extreme climate conditions in the Balkan Range Mountains, Bulgaria

Popa I, Caisan V [Presentation]
Oaks and beech response to drought in Republic of Moldova

Pyvovar T, Buksha I, Pasternak V, Buksha M [Presentation]
Results of the long-term crown condition survey on the UNECE ICP Forests monitoring plots Level I in Ukraine

Rakić M, Hansman J, Forkapić S, Bikit K, Mrđa D, Karaman M [Poster]
Activity concentrations of 137Cs and 40K in macrofungal species from several forest habitats in Serbia

Raspe S, Zimmermann L, Stiegler J, Dietrich H-P [Presentation]
Effects of drought years on forest ecosystems in Bavaria

Richard B, Archaux F, Aubert M, Boulanger V, Corcket E, Dupouey J-L, Gillet F, Langlois E, Macé S, Montpied P, Nicolas M, Lenoir J [Presentation]
The main determinants of the climatic debt in understory forest plant communities

Schermer É, Bel-Venner M-C, Fouchet D, Siberchicot A, Boulanger V, Caignard T, Thibaudon M, Oliver G, Nicolas M, Gaillard J-M, Delzon S, Venner S [Presentation]
Pollen limitation as a main driver of fruiting dynamics in oak populations

Schwärzel K [Presentation]
Effect of rainfall on green and blue water flows in a dryland forest plantation: A process-based comparative analysis

Sidor CG, Popa I, Vlad R [Poster]
Impact of local industrial pollution on conifers radial growth

Socha J, Tyminska-Czabanska L [Presentation]
Modelling of the long term changes of growth conditions for forest forming tree species using combined field observations and remote sensing data

Solberg S [Keynote Presentation]
Satellite remote sensing: An extension for ICP Forests?

Šrámek V, Neudertová Hellebrandová K, Fadrhonsová V, Vejpustková M [Presentation]
Effect of summer drought 2018 on the soil moisture content and radial increment of main forest tree species in the Czech Republic

Taşdemir C, Öztürk S, Akkaş E [Presentation]
Evaluation of defoliation and fruit yield in *Pinus brutia* within the scope of monitoring of forest ecosystems

Temerit A, Öztürk S, Aktaş Ö [Presentation]
Forest ecosystems monitoring and assessment in Turkey

Toigo M, Nicolas, Croisé L, Delport F, Landmann G, Jonard M, Nageleisen L-M, Belouard T, Jactel H [Presentation]
Temporal trends in tree defoliation and response to multiple biotic and abiotic stresses

Verstraeten A, Gottardini E, Bruffaerts N, De Vos B, Vanguelova E, Cristofolini F, Genouw G, Nussbaumer A, Neumann M [Presentation]
Tree pollen modifies throughfall biochemistry during spring

Yurdabak HC, Öztürk S [Presentation]
Effects of air pollution on forest ecosystems: preliminary results and evaluation of the ICP Forests network measurements in Turkey

4

ONGOING RESEARCH PROJECTS USING THE ICP FORESTS DATA AND/OR 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 47 projects using ICP Forests data and/or infrastructure and that were ongoing for at least one month between January and December 2019. In this period, 13 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
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
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
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
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

[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]
125	Tanja Sanders	Thünen Institute of Forest Ecosystems, Eberswalde	Extending trait-based dynamic global vegetation model (LPJmL-FIT) to temperate forests	Internal
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
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
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
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
152*	Tanja Sanders	ICP Forests Expert Panel on Forest Growth	Analysis of tree mortality in the ICP Forests Level I network	Internal

PROJECTS

ID	Name of Applicant	Institution	Project Title	External/ Internal[3]
153	Anne-Katrin Prescher	Programme Co-ordinating Centre of ICP Forests	Calibration and validation of a litter decomposition model for forest ecosystems	Internal
155*	Stefan Klesse	Swiss Federal Research Institute (WSL)	Biological invasion pattern and ash growth dynamics	External
157*	Peter Waldner	Swiss Federal Research Institute (WSL)	Mapping the spectral imprint of the 2018 drought at the ICP Forests plots	Internal
158	Sönke Zaehle	Max Planck Institute for Biochemistry	Quantifying the effects of interacting nutrient cycles on terrestrial biosphere dynamics and their climate feedbacks (QUINCY)	External
159*	Dirk Schindler	Albert-Ludwigs Unversity of Freiburg	Minimization of storm damage risk in forests considering climate change	External
161	Rupert Seidl	University of Natural Resources and Life Sciences (BOKU) Vienna, Austria	Forest disturbance in a changing world	External
162	Lisa Hülsmann	Group for Theoretical Ecology - University of Regensburg	BayForDemo - Strategies for adapting Bavarian forests to climate change based on the simulation of demographic processes	External
163*	Kailang Yu	Department of Environmental Science - ETH Zurich	Assessing self-thinning trajectories across landscapes and its implications on carbon storage	External
164*	Xavier Morin	Centre National de la Recherche Scientifique (CNRS)	Predicting stand productivity with the FORCEEPS model and testing diversity effects across European forests	External
165*	Rose Abramoff	Laboratoire des Sciences du Climate et de l'Environnement, France	Maximum capacity of mineral-sorbed organic matter	External
168*	Colin Averill	ETH Zürich, Switzerland	Microbiome-enabled forecasting of forest composition and function	External
171*	Jaroslaw Socha	University of Agriculture, Krakow, Poland	Innovative forest management strategies for a resilient bioeconomy under climate change and disturbances	External
172	Baitian Wang	Beijing Forestry University, China	Soil and water conservation landscape optimization technique and demonstration in loess gully region	External
174*	Herve Cochard	INRA, Institut National de Recherche en Agronomie, France	Hydrauleaks: Assessing the role of drought and heat stresses on forest canopy mortality	External
175*	Wim de Vries	Wageningen University & Research WUR, The Netherlands	Impacts of urban and livestock footprints on plant leaf nutrition in Europe	External
176*	Stephanie Rehschuh	Karlsruhe Institute for Technology, Institute for Meteorology and Climate Research, Atmospheric Environmental Research, Germany	Admixing other tree species to European beech forests: Effects on soil organic carbon and total nitrogen stocks - a review	External
177	Nenad Potočić	Croatian Forest Research Institute, Croatia	Vitality of common beech (*Fagus sylvatica* L.) in changing climate conditions	Internal
178*	Alexander Shenkin	University of Oxford, UK	Global estimate of woody surface area	External

PART B
Reports on individual surveys in ICP Forests

5

ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2018

Aldo Marchetto, Peter Waldner, Arne Verstraeten, Daniel Žlindra

Summary

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. Pollutant flux towards ecosystems through deposition mainly follows two pathways: wet deposition of compounds dissolved in rain, snow, sleet or similar, and dry deposition of particulate matter through gravity or adsorption on forest canopy for example.

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 2018, the chemical composition of atmospheric deposition was measured in 293 ICP Forests Level II permanent plots throughout Europe.

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

High values of nitrate deposition were mainly found in central Europe (Germany, Denmark, Belgium and eastern Austria), while for ammonium they were also found in northern Italy and Poland. The area of high deposition is smaller for sulphate, including some plots in Germany, Greece and Poland. High sulphate values are also measured in Belgium, but they are partially due to deposition of marine aerosol, and they are less evident after sea-salt correction.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in eastern Europe. The correction for the marine contribution of calcium matters mainly for sites in central Europe and in Spain. On the contrary, in the case of magnesium, the distribution of the highest values is markedly reduced by the sea salt correction.

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.

In the last century 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-}), derived from marine aerosol and from sulphuric acid formed in the atmosphere by the interaction of gaseous sulphur dioxide (SO_2) with water.

SO_2 emission derives from coal and fuel combustion, volcanoes, and forest fires and has increased since the 1850s, causing an increase in the deposition of sulphate and in deposition acidity. Acidifying inputs can be partly buffered by the deposition of the base cations calcium (Ca^{2+}) and magnesium (Mg^{2+}).

Natural sources of nitrogen (N) in the atmosphere are mainly restricted to the emission of N_2O and N_2 during denitrification and the decomposition of the nitrogen gas molecule in the air during lightning. However, human activities cause the emission of large amounts of nitrogen oxides (NO_x), released during combustions, and of ammonia (NH_3) deriving from agriculture and farming. They are found in atmospheric deposition in the form of nitrate (NO_3^-) and ammonium (NH_4^+).

Nitrogen compounds have two effects on the ecosystems: they are important plant nutrients that can produce ecosystem eutrophication, and both have strong effects on plant metabolism (e.g., Silva et al. 2015), forest ecosystem processes (e.g. Meunier et al. 2016) and biodiversity (e.g., Bobbink et al. 2010), but they can also act as acidifying compounds (Bobbink and Hettelingh 2011).

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

Materials and methods

Atmospheric deposition is collected in the ICP Forests permanent plots under the tree canopy (throughfall samplers, Fig. 5-1 right) and in a nearby clearance (open field samplers, Fig. 5-1 left). Throughfall samples are used to estimate wet deposition, i.e. the amount of pollutants carried out by rain and snow, but they also include dry deposition from particulate matter collected by the canopy. The total deposition to a forest, however, also includes nitrogen taken up by leaves directly or organic nitrogen compounds. It can be estimated by applying canopy exchange models.

It is important to note the different behaviour of individual ions when they interact with the canopy: in the case of sulphate, calcium and magnesium, the interaction is almost negligible and it can be assumed that throughfall deposition includes the sum of wet and dry deposition.

This is not the case for other ions, such as ammonium: tree canopy and the associated microbial communities strongly interact with them, for example tree leaves can uptake ammonium ions and release potassium ions and organic compounds, affecting the composition of throughfall deposition.

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, use of control chart and performing conductivity and ion balance checks on all samples (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).

In this report, we consider the 2018 yearly throughfall deposition, collected in 293 permanent plots and following the ICP Forests Manual, in both the European ICP Forests network and in the Swedish Throughfall Monitoring Network (SWETHRO).

Thirteen plots were excluded because the duration of sampling covered less than 90% (329 days) of the year, and 63 other plots were marked as "not validated" because the conductivity check was passed for less than 30% of the analysis of the year. Two plots were also marked as the laboratory did not participate in the mandatory Working Ring Test.

Finally, ammonium deposition reported by two laboratories for 11 plots and calcium deposition reported by one laboratory for two 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 Integrated Monitoring Manual (FEI 2013).

Results

The uneven distribution of emission sources and receptors and the complex orography of part of Europe results in a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in deposition arise. In the case of nitrate, high and moderate throughfall deposition was mainly found in central Europe, including Germany, Czechia, Poland, Austria, Italy, Slovenia and Belgium, but single plots with high deposition values are also reported in other countries (Fig. 5-3).

The central European area of high and moderate ammonium throughfall deposition is larger than for nitrate, with higher throughfall deposition values particularly in southern Germany and northern Italy, western Slovakia and Poland (Fig. 5-4).

It is generally considered that negative effects of nitrogen deposition on forests become evident when inorganic nitrogen deposition (i.e. the sum of nitrate and ammonium deposition) is higher than a specific threshold, known as the critical load. Critical loads can be evaluated for each site by modeling, but more generic critical loads (empirical critical loads) are also being evaluated, ranging between 10 and 25 kg ha^{-1} y^{-1} (Bobbink and Hettelingh, 2011). In 2018, throughfall inorganic nitrogen deposition higher than 10 kg ha^{-1} y^{-1} were mainly measured in central Europe, including Germany, Belgium, northern Italy, Switzerland, Austria, and Czechia) (Fig. 5.5).

Figure 5-1: Open field (left) and throughfall (right) collectors at an ICP Forests Level II site in Slovenia (Images: Iztok Sinjur and Lado Kutnar, SFI)

The area with high and moderate throughfall deposition of sulphate is smaller than for the nitrogen compounds (Fig. 5-6): it includes Belgium, Italy, Slovenia and an area between Germany, Czechia, Slovakia and Poland. Further plots with high sulphate throughfall deposition were found in proximity of large point sources and harbors in Spain, Greece, France and Austria.

The influence of marine aerosol was relevant at sites with intermediate sulphate throughfall deposition in coastal areas, where the correction for sea-salt contribution led to low throughfall deposition values, without relevant alterations in the pattern described above (Fig. 5-7).

Calcium and magnesium are also analysed in the ICP Forests deposition monitoring network, as their deposition can buffer the acidifying effect of atmospheric deposition, protecting soil from acidification. High values of calcium throughfall deposition are mostly reported in central and southern Europe (Fig. 5-8).

The correction for the marine contribution was more relevant for sites in central Europe with intermediate calcium deposition (Fig. 5-9): high sea-salt corrected calcium deposition is mainly found in southern Europe (Spain, Italy and Greece) and the Alps (Austria and Switzerland) were the influence of wind-blown Saharan dust is remarkable.

On the contrary, in the case of magnesium, the distribution of the highest values, including a large portion of southern and central Europe (Fig. 5-10), is markedly reduced by the sea salt correction (Fig. 5-11).

Within the ICP Forests programme, deposition monitoring is running continuously since 1997 in 64 permanent Level II plots. During this period, the application of the protocol of the Air Convention and economic transformation led to a marked decrease of SO_2 emission in Europe (EEA 2016). As a consequence, sea-salt corrected sulphate throughfall deposition dramatically decreased in the considered period (Fig. 5-2), reaching values as low as 30% of those found in the late 1990s, and causing a similar decrease of deposition acidity (Waldner et al. 2014). In the case of the nitrogen compounds, the average reduction in throughfall deposition was also present, but less marked. Note that total deposition of nitrogen typically is a factor 1 to 2 higher than throughfall deposition, due to uptake in the canopy.

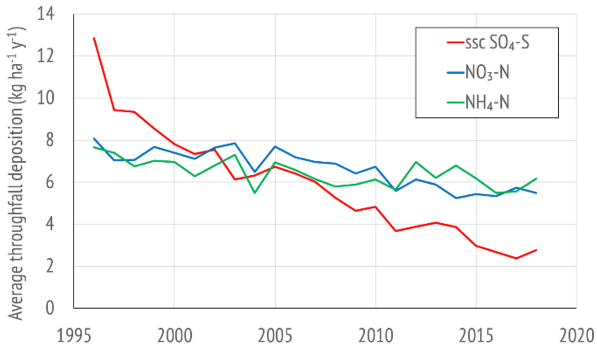

Figure 5-2: Trend in throughfall deposition of nitrate-nitrogen (NO_3^--N), ammonium-nitrogen (NH_4^+-N) and sea-salt corrected sulphate-sulphur (SO_4^{2-}-S) (kg ha^{-1} yr^{-1}) measured between 1997 and 2018 in 64 ICP Forests Level II plots with continuous data (22 plots in DEU, 13 plots in FRA, 12 plots in AUT, 2 plots in GBR, 1 plot in DNK).

EVALUATIONS

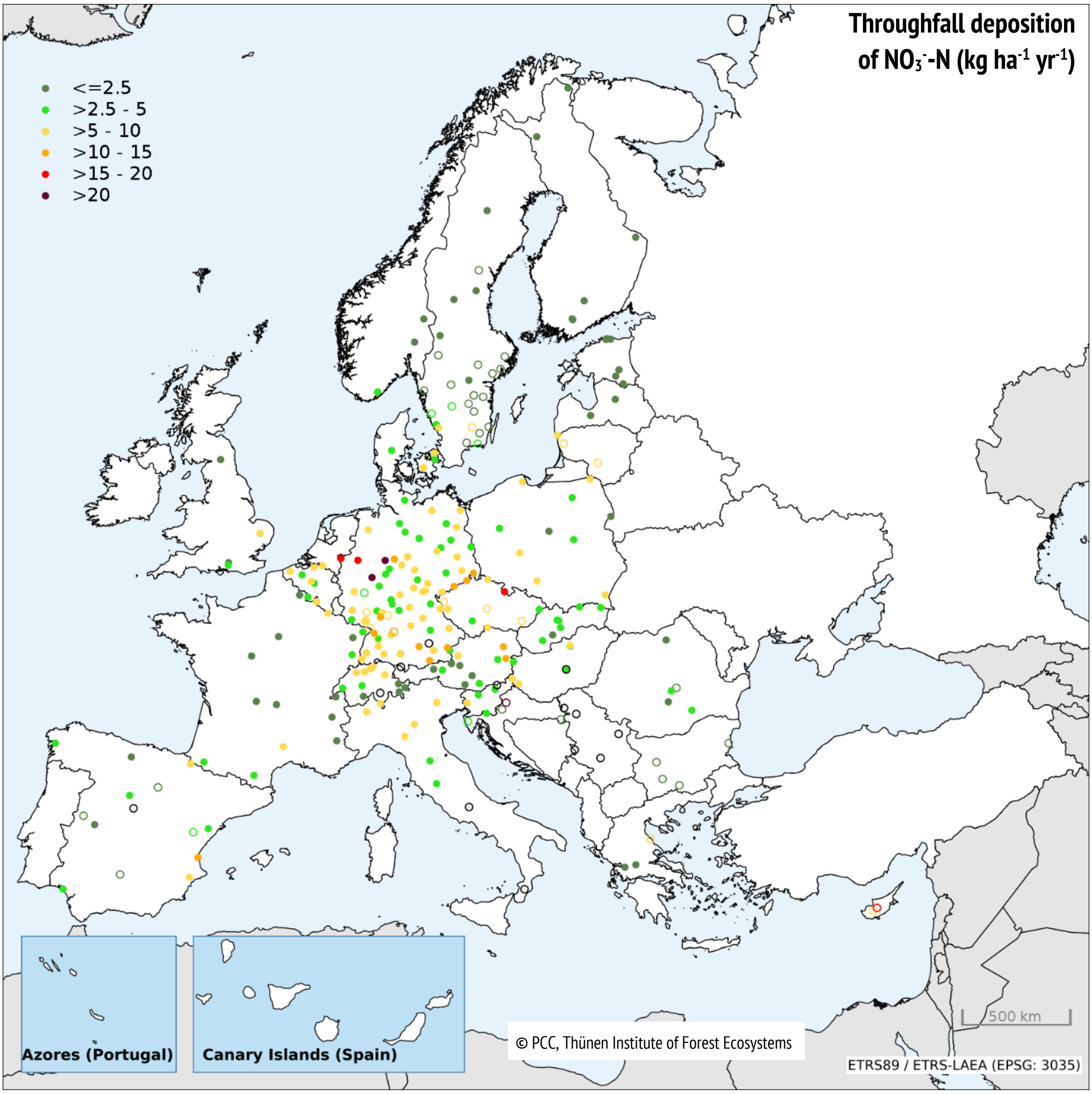

Figure 5-3: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Circles: not validated data. Black circles: monitoring period shorter than 330 days.

EVALUATIONS

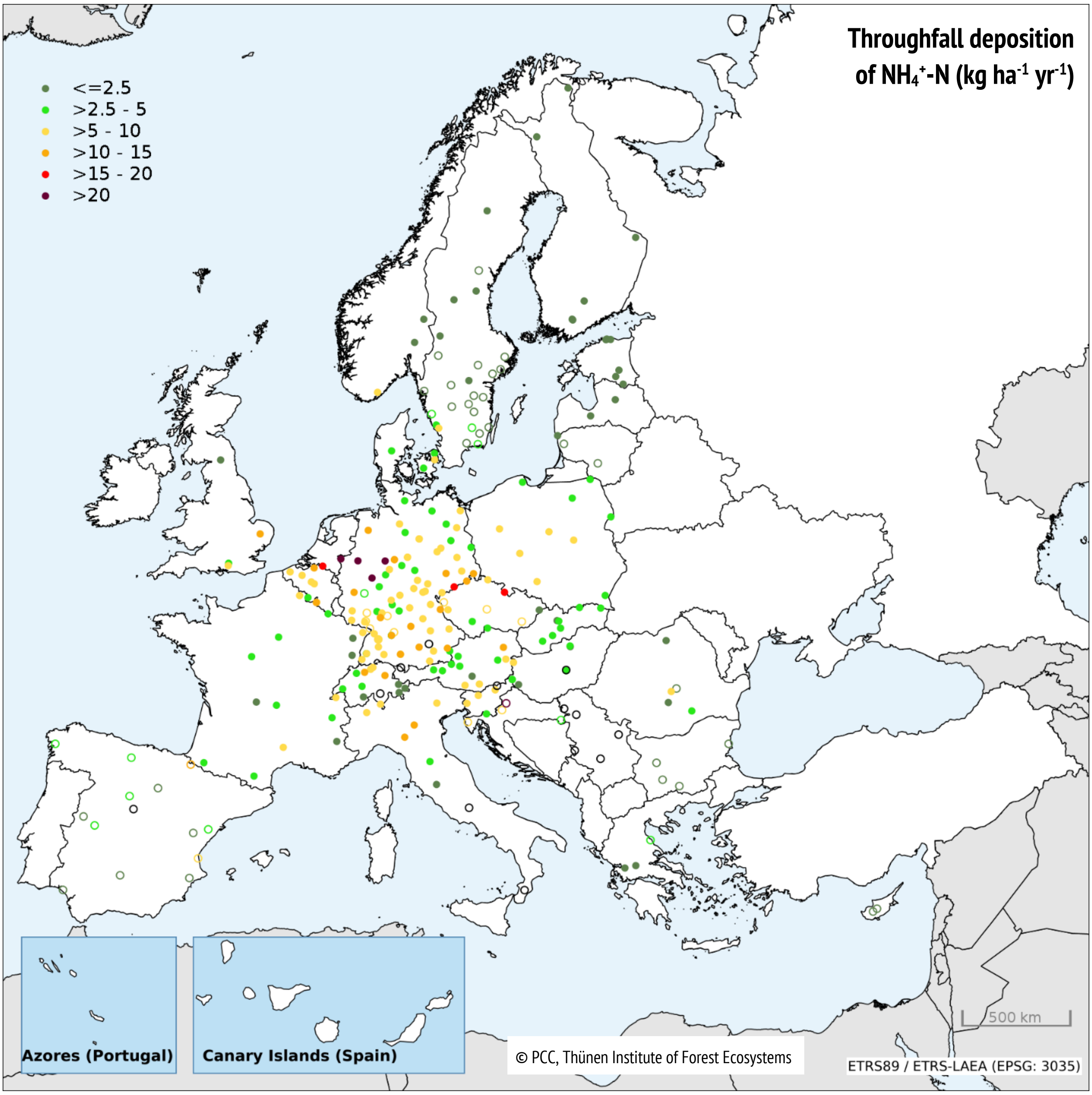

Figure 5-4: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter than 330 days.

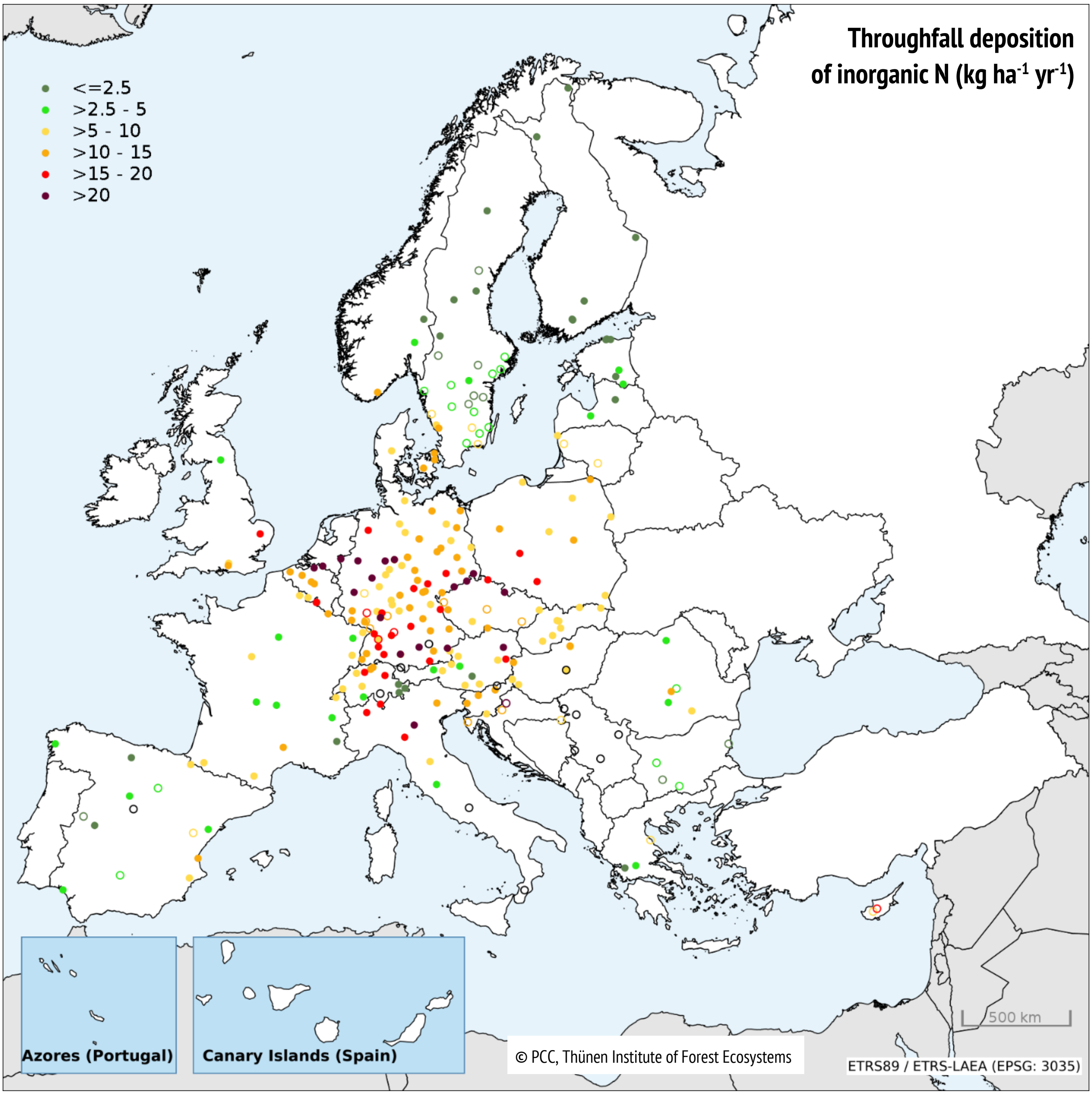

Figure 5-5: Throughfall deposition of inorganic nitrogen (NO_3^--N + NH_4^+-N) (kg N ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter than 330 days.

EVALUATIONS

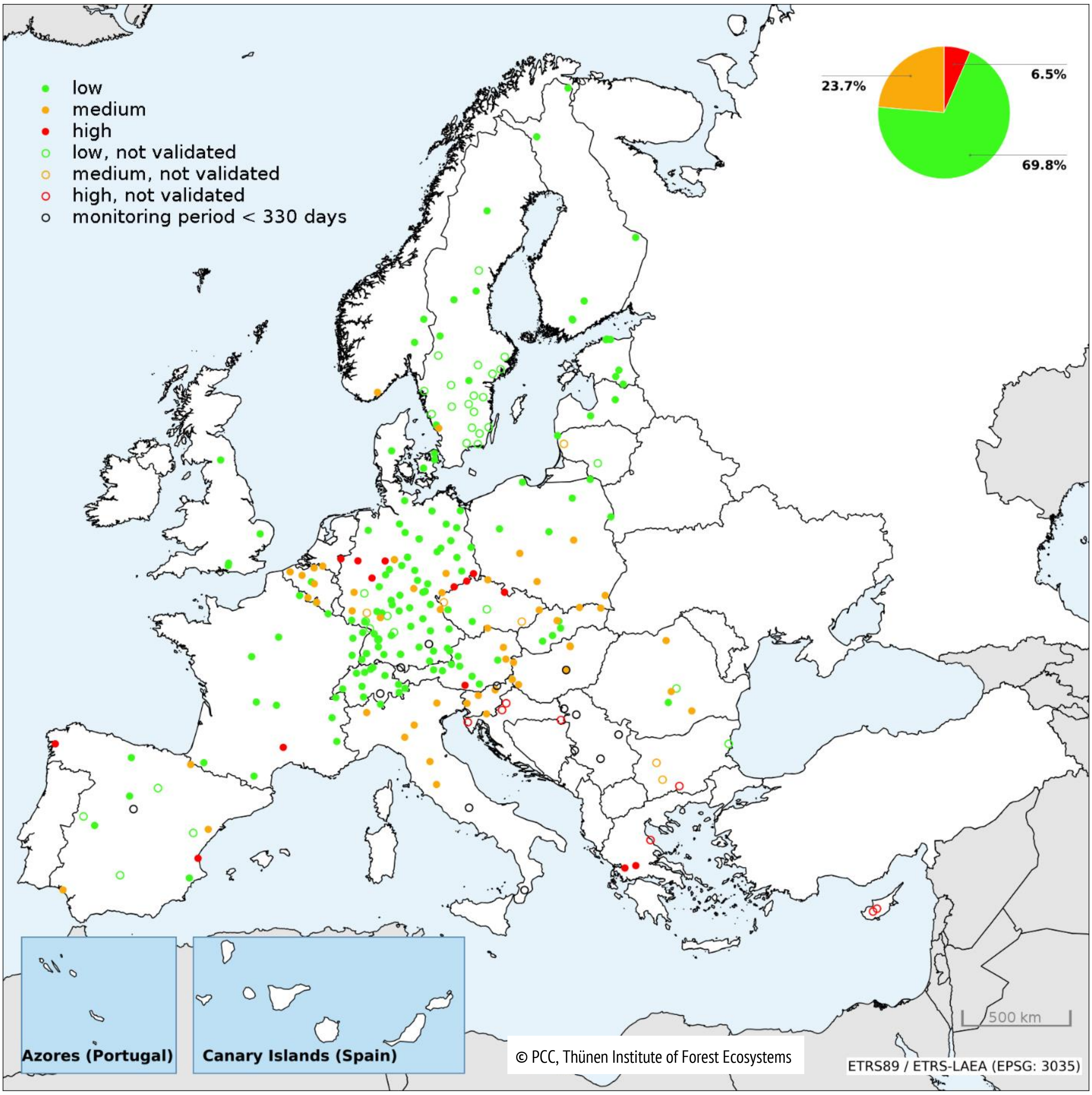

Figure 5-6: Throughfall deposition of sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter than 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}).

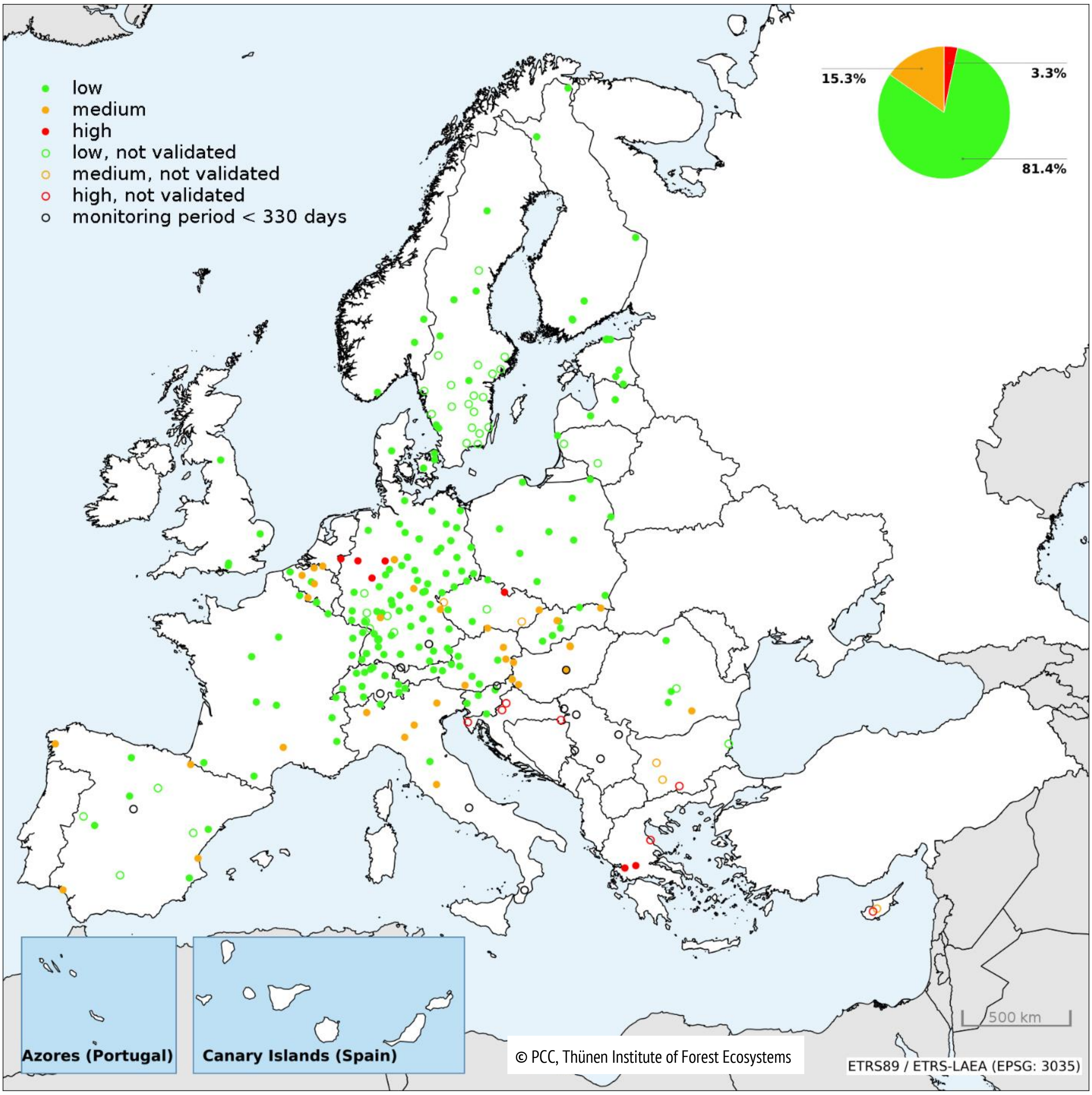

Figure 5-7: Throughfall deposition of sea-salt corrected sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring 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}).

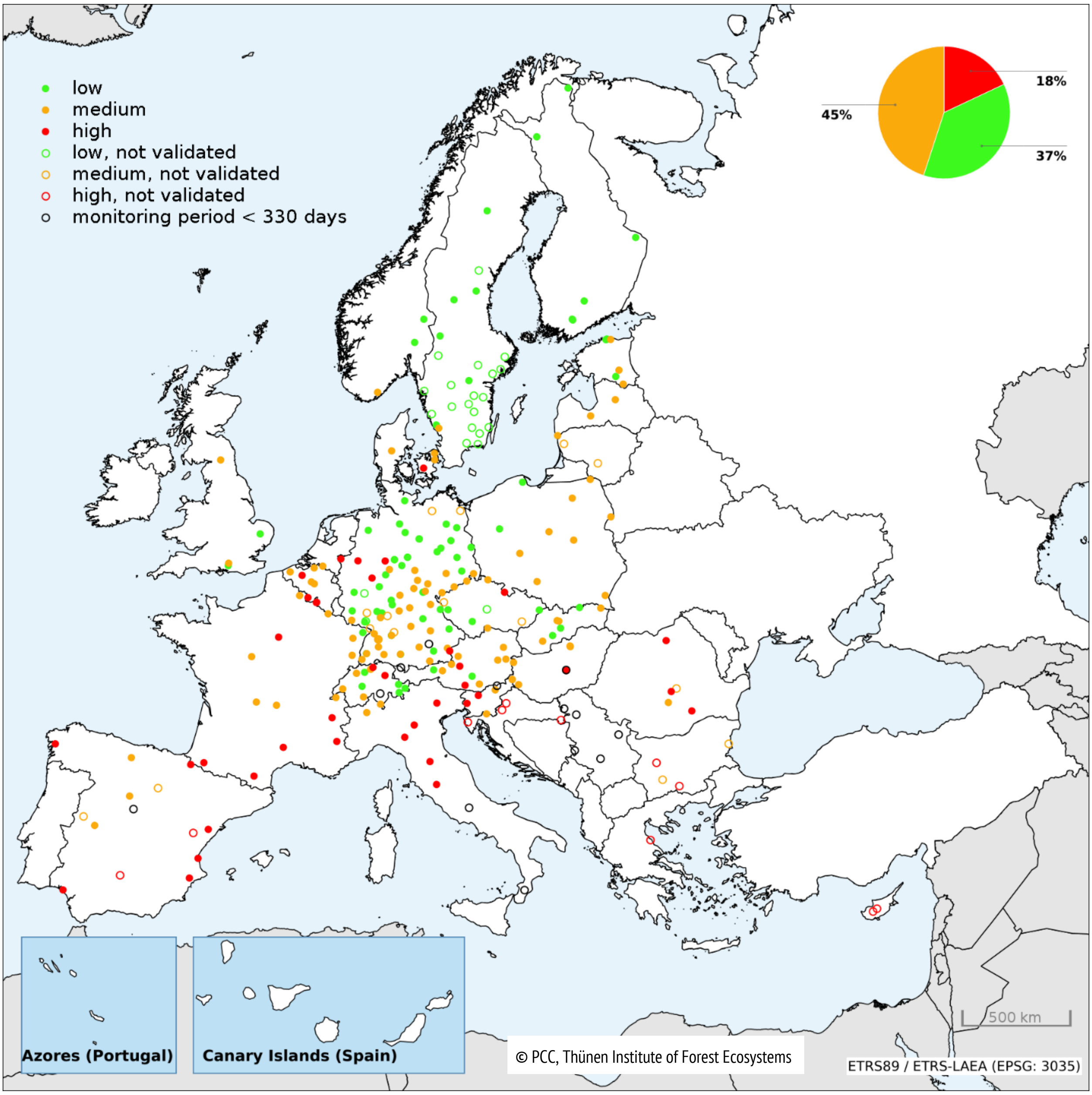

Figure 5-8: Throughfall deposition of calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: 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}).

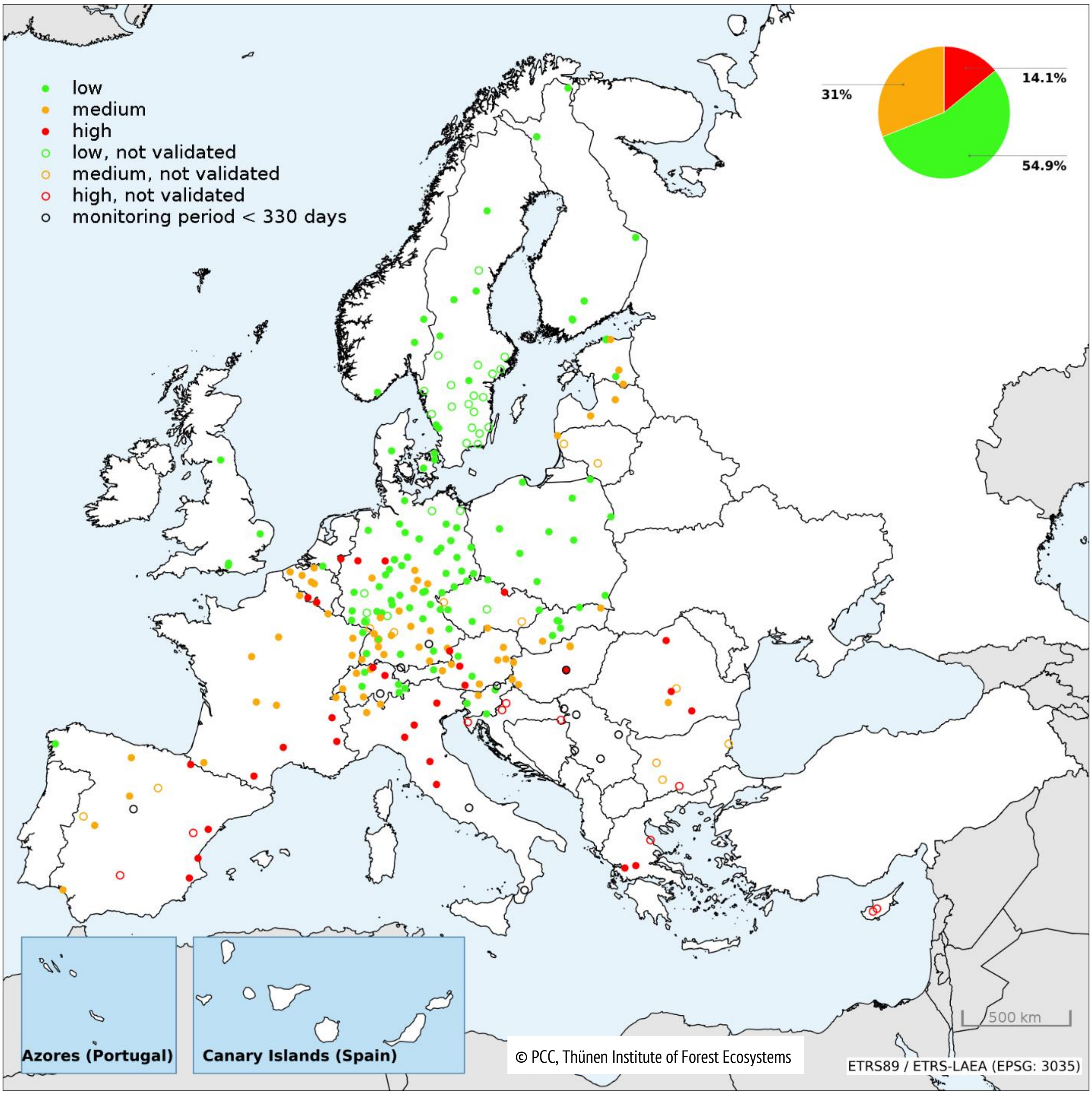

Figure 5-9: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter 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}).

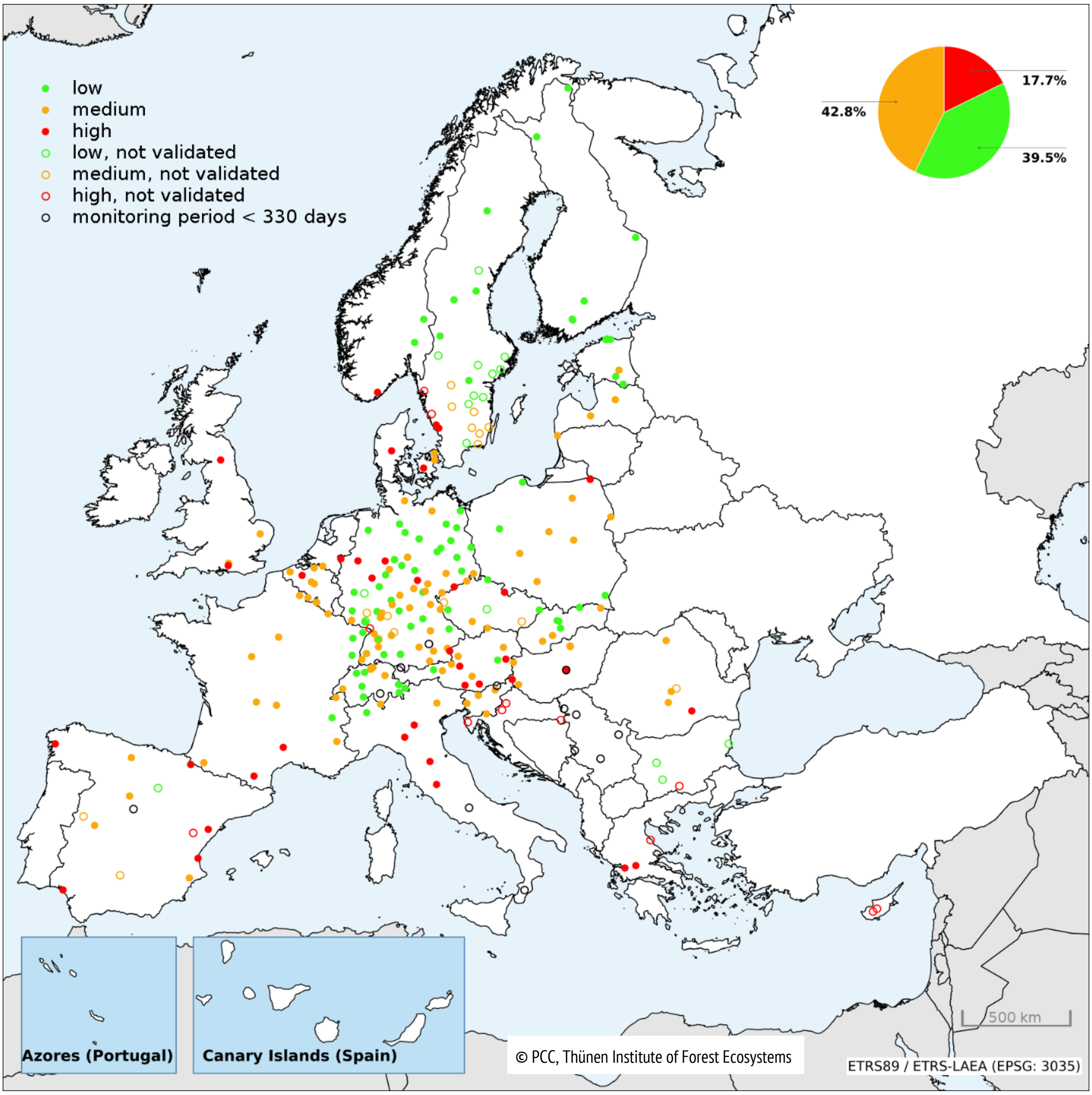

Figure 5-10: Throughfall deposition of magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter than 330 days. 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}).

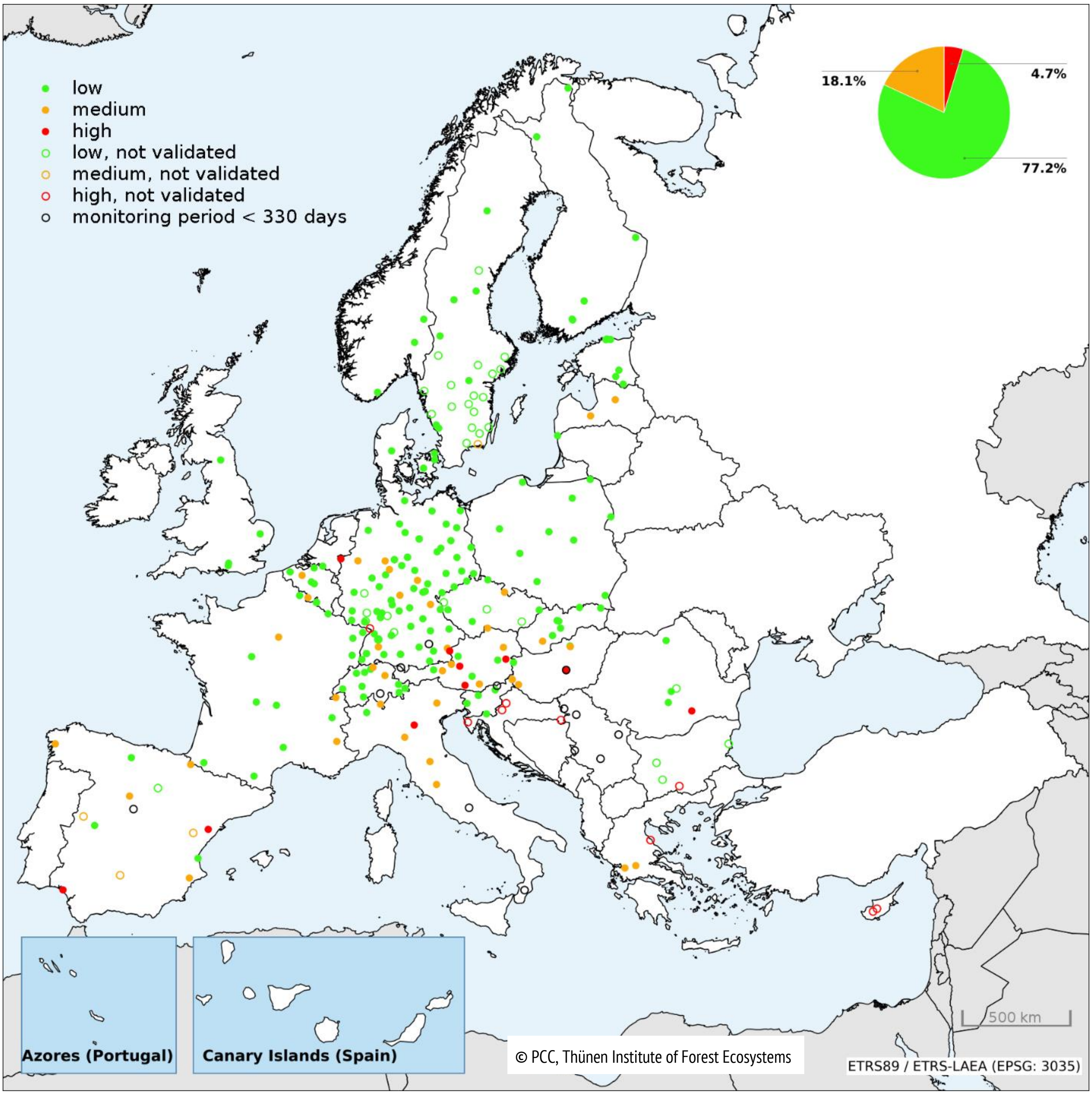

Figure 5-11: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2018 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Coloured dots: validated data. Coloured circles: not validated data. Black circles: monitoring period shorter 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}).

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6

TREE CROWN CONDITION IN 2019

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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 .

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 2019, as well as long-term trends for the main species and species groups.

Methods of the 2019 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 (Eickenscheidt 2015, Dănescu 2019, Meining et al. 2019).

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 6-1). In the maps presenting the mean plot defoliation and in Table 6-4, class 2 is subdivided into class 2-1 (> 25–40%) and class 2-2 (> 40–60% defoliation).

Table 6-1: 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 (standing dead trees only)

Table 6-2 shows countries and the number of plots assessed for crown condition parameters from 2010 to 2019, and the total number of sample trees submitted in 2019. 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 6-2: Number of plots assessed for crown condition parameters from 2010 to 2019 in countries with at least one Level I crown condition survey since 2010, and total number of sample trees submitted in 2019

Country	Plots 2010	2011	2012	2013	2014	2015	2016	2017	2018	Plots 2019	Trees 2019
Andorra	3	3	3	11	11	12					
Austria	135										
Belarus	410	416		373		377					
Belgium	9	9	8	8	8	8	53	53	52	52	551
Bulgaria	159	159	159	159	159	159	159	160	160	160	5 591
Croatia	83	92	100	105	103	95	99	99	99	97	2 328
Cyprus	15	15	15	15	15	15			15	15	365
Czechia	132	136	135		138	136	136	135	132	132	5 026
Denmark	17	18	18	18	18	18	17	17	17	17	406
Estonia	97	98	97	96	96	97	98	98	98	98	2 383
Finland	932	717	785								
France	532	544	553	550	545	542	533	527	521	515	10 399
Germany	411	404	415	417	422	424	421	416	410	421	10 094
Greece	98				57	47	23	36	40	45	1 055
Hungary	71	72	74	68	68	67	67	66	68	68	1 530
Ireland	29		20							28	589
Italy	253	253	245	247	244	234	246	247	249	237	4 593
Latvia	207	203	203	115	116	116	115	115	115	115	1 740
Lithuania	75	77	77	79	81	81	82	82	81	81	1 957
Luxembourg				4	4	4	4	3	3	4	96
Montenegro	49	49	49	49			49	49	49	49	1 176
Netherlands	11										
Norway	491	496	496	618	687	554	629	630	623	687	5 651
Poland	374	367	369	364	365	361	353	352	348	346	6 893
Rep. of Moldova								9	9		
Romania	239	242	241	236	241	242	243	246	246	247	6 036
Russian Fed.	288	295									
Serbia	121	119	121	121	128	127	127	126	126	127	2 984
Slovakia	108	109	108	108	107	106	103	103	101	100	4 499
Slovenia	44	44	44	44	44	44	44	44	44	44	1 065
Spain	620	620	620	620	620		620	620	620	620	14 880
Sweden	830	640	609	740	842	839	701	618	760	849	2 913
Switzerland	48	47	47	47	47	47	47	47	47	47	1 022
Turkey	554	563	578	583	531	591	586	598	601	597	13 837
United Kingdom	76										
TOTAL	7 521	6 807	6 189	5 795	5 697	5 343	5 555	5 496	5 634	**5 798**	**109 659**

- 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 crown condition on the Level I network in 2019, *Pinus sylvestris* was the most abundant tree species (16.7% of all trees), followed by *Picea abies* (11.8%), *Fagus sylvatica* (11.4%), *Pinus nigra* (4.9%), *Quercus petraea* (4.2%), *Quercus robur* (4.1%), *Quercus ilex* (3.6%), *Pinus brutia* (3.2%), *Quercus cerris* (3.1%), *Betula pubescens* (2.4%), *Pinus halepensis* (2.4%), *Quercus pubescens* (2.1%), *Betula pendula* (2.1%), *Abies alba* (2.0%) and *Pinus pinaster* (1.8%). Most Level I plots with crown condition assessments contained one (49.5%) or two to three (38.1%) tree species per plot. On 10.2% of plots four to five tree species were assessed, and only 2.2% of the plots featured more than five tree species. In 2019, 49.9% of the assessed trees were broadleaves and 50.1% 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 6-4 and 6-5). 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 6-3 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 6-2a-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 2000–2019. 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 2011–2019 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 6-3). 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 6-3: Information on the monitoring design for the national crown condition surveys in the participating countries in 2019

Country	Total area (1000 ha)	Forest area (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	No information available for 2019				
Andorra	No information available for 2019				
Austria	No information available for 2019				
Belarus	No information available for 2019				
Belgium-Flanders	1351	146	4x4	71	1474
Belgium-Wallonia	1684	555	varying	47	372
Bulgaria	11100	4257	4x4/16x16	160	5591
Croatia	5659	2795	16x16	97	2328
Cyprus	925	298	16x16	15	365
Czechia	7887	2673	16x16	125	4538
Denmark	4293	627	varying	377	2376
Estonia	4534	2331	16x16	98	2286
Finland	No information available for 2019				
France	54883	16814	16x16	524	10668
Germany	35721		16x16	421	10128
Greece	13205	6513	16x16	46	1055
Hungary	9300	1939	16x16	78	1869
Ireland	No information available for 2019				
Italy	30128	10345	16x16	237	4166
Latvia	6459	3223	16x16	115	1732
Lithuania	6529	2197	4x4/16x16	992	5956
Luxembourg	259	91	4x4	49	1176
North Macedonia	No information available for 2019				
Rep. of Moldova	3385	374	3x3	618	16676
Montenegro	1381	827	16x16	49	1176
Netherlands	No information available for 2019				
Norway	32381	12210	3x3	1863	10563
Poland	31268	9255	8x8	2042	40840
Portugal	No information available for 2019				
Romania	23839	6565	16x16	249	
Russian Fed.	No information available for 2019				
Serbia	8836	2360	4x4/16x16	130	2990
Slovakia	4904	2014	16x16	100	3712
Slovenia	2027	1238	16x16	44	1056
Spain	49880	18289	16x16	620	14880
Sweden	47496	27881	varying	4857	7795
Switzerland	4129	1279	16x16	47	1004
Turkey	77846	22300	16x16	599	13738
Ukraine	No information available for 2019				
United Kingdom	No information available for 2019				
Total				**14 670**	**170 510**

EVALUATIONS

Results of the transnational crown condition survey

Defoliation

The transnational crown condition survey in 2019 was conducted on 109 659 trees on 5 798 plots in 27 countries (Table 6-2). Out of those, 103 831 trees were assessed in the field for defoliation (Table 6-4).

The overall mean defoliation for all species was 23.3% in 2019; there was a slight increase in defoliation for both conifers and broadleaves in comparison with 2018 (Table 6-4). Broadleaved trees showed a higher mean defoliation than coniferous trees (23.2% vs. 22.2%). Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' and 'slight' (73.4% combined) than broadleaves (69.7%) and a lower frequency of trees with more than 60% defoliation (2.9% vs. 3.7%).

Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (28.6% and 26.9%, respectively). Common beech had the lowest mean defoliation (21.0%) followed by deciduous (sub-) Mediterranean oaks (21.2%) and Norway spruce with 22.0%. Mediterranean lowland pines had the highest percentage (75.8%) of trees with ≤ 25% defoliation, while deciduous temperate oaks had the lowest (58.3%). The strongest increase occurred in evergreen oaks (2.5%) and Mediterranean lowland pines (1.5%).

Mean defoliation of all species at plot level in 2019 is shown in Figure 6-1. More than two thirds (68.4%) 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 the Pyrenees through southeast (Mediterranean) France to northwest Italy, but also from central and northern France through Germany and into Czechia, Slovakia and Hungary, and in western Bulgaria. Plots with low mean defoliation were found across Europe, but mainly in Norway, Sweden, Estonia, Romania, central Serbia, Greece and Turkey.

The following sections describe the species-specific mean plot defoliation in 2019 and the over-all trend and yearly mean plot defoliation from 2000 to 2019. For maps on defoliation of individual tree species in 2019, please refer to the online supplementary material[1].

Table 6-4: Percentage of trees assessed in 2019 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2018 in parentheses) and the number of trees in each group. Class 4 contains standing dead trees only. 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 >60-99%	Class 4 100%	Mean defoliation	No. of trees
Scots pine (*Pinus sylvestris*)	22.4	52.0	15.7	6.2	3.0	0.6	22.8 (+0.7)	17 936
Norway spruce (*Picea abies*)	31.9	37.2	20.2	6.6	2.8	1.4	22.0 (+0.9)	12 495
Austrian pine (*Pinus nigra*)	29.1	43.8	15.0	7.1	4.8	0.3	22.9 (+0.8)	5 302
Mediterranean lowland pines	14.7	61.1	16.3	5.1	1.9	0.8	22.8 (+1.5)	8 382
Other conifers	35.0	41.0	15.5	5.9	2.3	0.2	20.2 (+0.7)	7 931
Common beech (*Fagus sylvatica*)	34.7	38.4	17.4	6.7	2.7	0.2	21.0 (+0.2)	12 599
Deciduous temperate oaks	19.1	39.2	27.7	9.7	3.9	0.4	26.9 (+1.0)	8 912
Dec. (sub-) Mediterranean oaks	30.6	43.6	16.5	6.5	2.4	0.4	21.2 (+/-0)	8 093
Evergreen oaks	7.0	52.8	25.7	9.1	5.3	0.2	28.6 (+2.5)	4 602
Other broadleaves	30.2	43.3	14.6	5.9	4.4	1.5	22.4 (-0.4)	17 579
TOTAL								
Conifers	26.0	47.4	16.8	6.2	2.9	0.7	22.2 (+0.9)	52 046
Broadleaves	27.4	42.3	18.8	7.1	3.7	0.7	23.2 (+0.3)	51 785
All species	26.7	44.9	17.8	6.6	3.3	0.7	23.3 (+0.7)	103 831

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

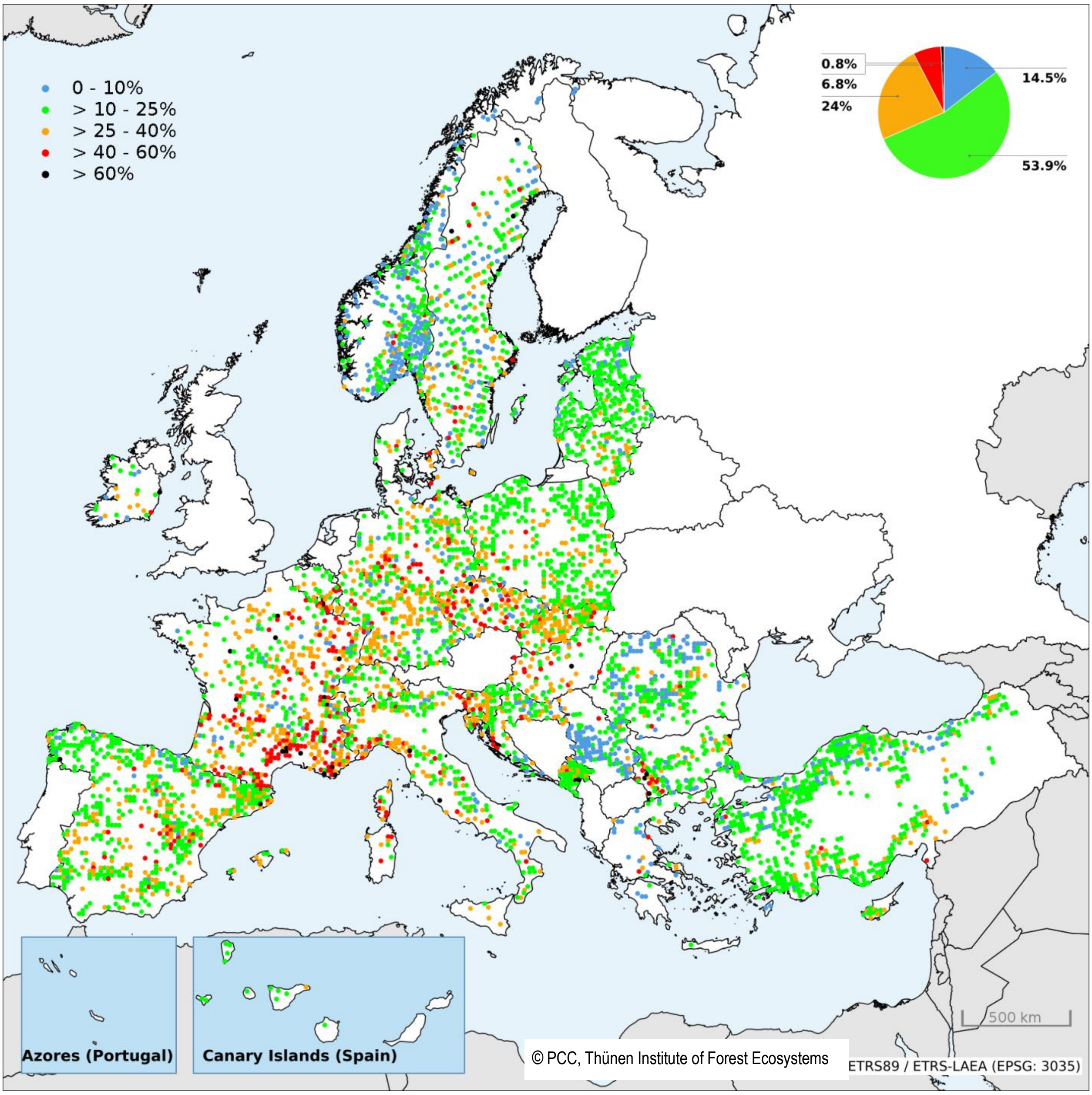
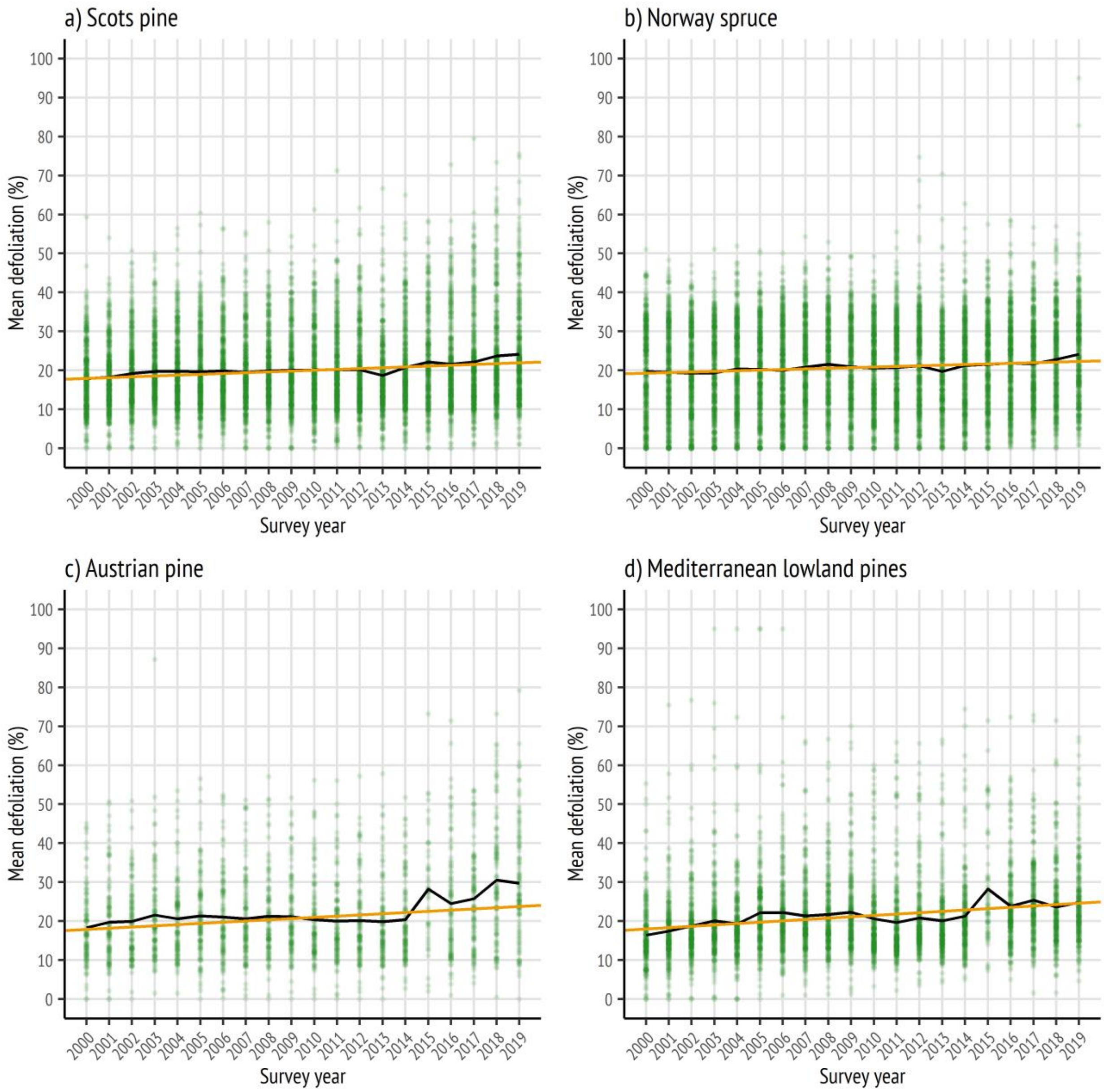
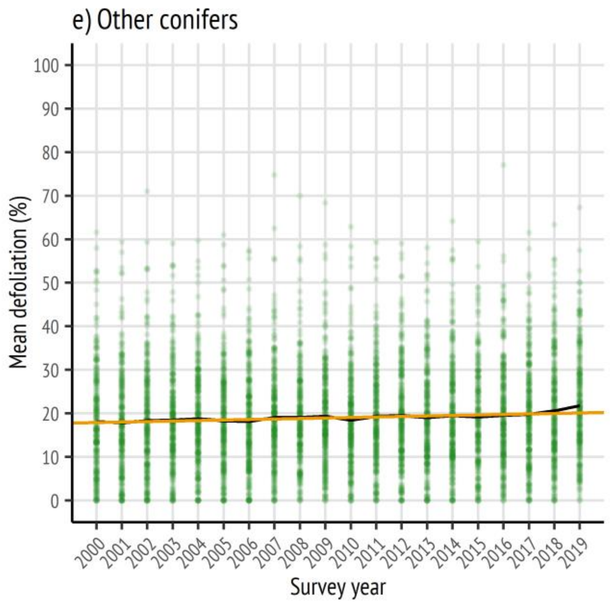
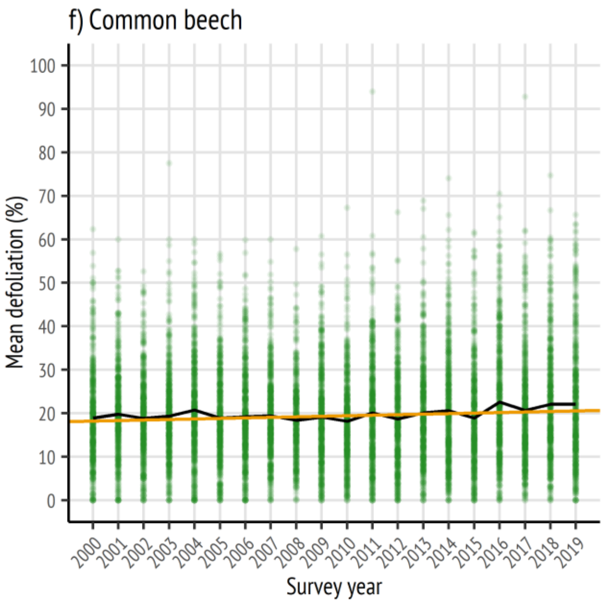


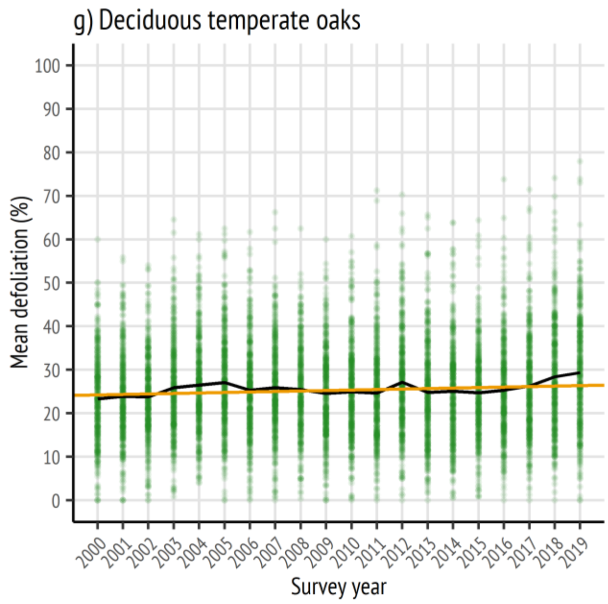
Figure 6-1: Mean plot defoliation of all species in 2019, shown as defoliation classes. The legend (top left) shows defoliation classes ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) shows the percentage of plots per defoliation class. Dead trees are not included.

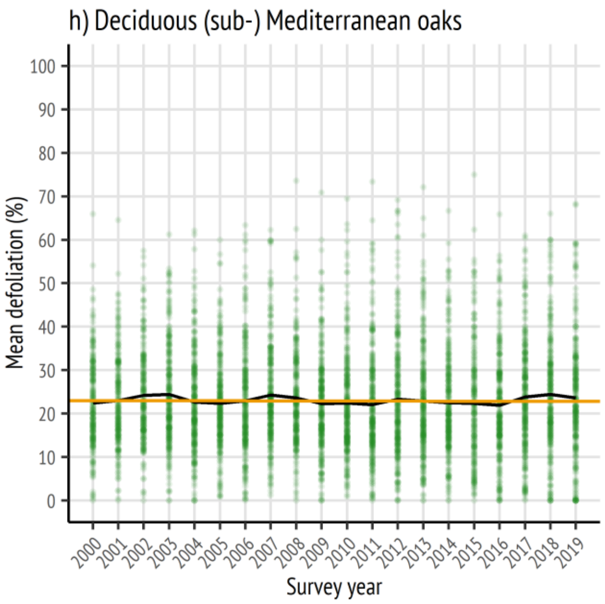


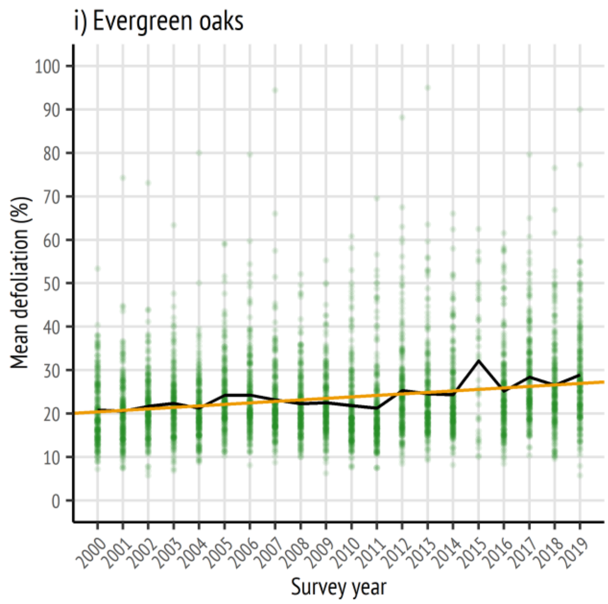


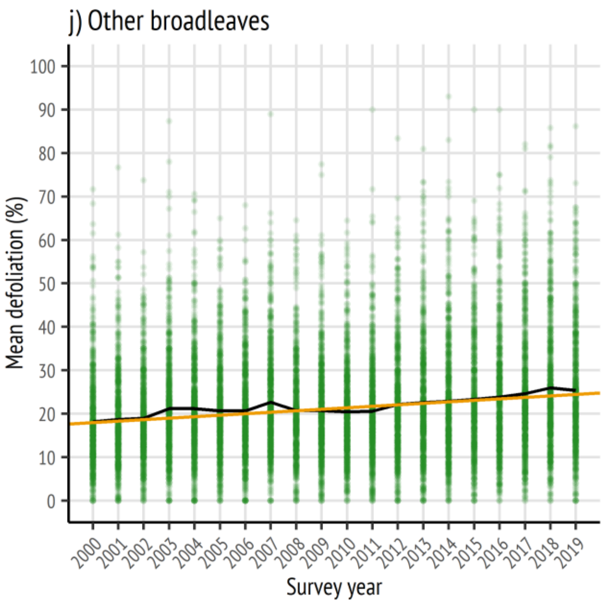
Figures 6-2 a-e: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2000–2019; points represent annual plot mean values: (a) Scots pine (regional Sen's slope = 0.2114, p < 0.001) (b) Norway spruce (regional Sen's slope = 0.1596, p < 0.001) (c) Austrian pine (regional Sen's slope = 0.3102, p = 0.0150) (d) Mediterranean lowland pines (regional Sen's slope = 0.3464, p < 0.001) (e) Other conifers (regional Sen's slope = 0.1160, p < 0.001)











Figures 6-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2000–2019; points represent annual plot mean values: (f) Common beech (regional Sen's slope = 0.1223, $p < 0.0350$) (g) Deciduous temperate oaks (regional Sen's slope = 0.1146, $p = 0.0478$) (h) Deciduous (sub-) Mediterranean oaks (regional Sen's slope = -0.0116, $p = 0.6732$) (i) Evergreen oaks (regional Sen's slope = 0.3435, $p < 0.001$) (j) Other broadleaves (regional Sen's slope = 0.3425, $p < 0.001$)

Scots pine

Scots pine (*Pinus sylvestris*) was the most frequent tree species in the Level I network in 2019. 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, pine trees showed no (≤10%) or only slight mean defoliation (≤25%) in 2019; 15.3% and 63.1%, respectively, and 78.4% combined for defoliation classes 0 and 1 (please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 20.9% of the plots was moderate (>25–60% defoliation, class 2) and on 0.7% of the plots severe (>60% defoliation, class 3). 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 trend of mean plot defoliation of Scots pine over the course of the last 20 years (an increase of 4.2%, Figure 6-2a). The mean defoliation across plots showed some fluctuation towards the end of the chosen reporting period, with mean defoliation values steadily above the trend line since 2015.

Norway spruce

Norway spruce (*Picea abies*) is the second most frequently assessed species on Level I plots in 2019. 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 2019, Norway spruce trees on one quarter (24%) of all Norway spruce plots had defoliation up to 10%, and 42.7% had slight defoliation. Taken together, one third of the spruce plots (66.7%) had mean defoliation between 0 and 25% (please refer to the online supplementary material[1], Figure S1-2). On 32.5% of the plots defoliation was moderate (>25–60% defoliation) and severe defoliation was recorded on only 0.7% 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 20-year trend in mean plot defoliation of Norway spruce shows an increase of 3.2% (Figure 6-2b). The annual mean values did not deviate much from the trend line except in 2013 and 2019.

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 10% on 11.9% of the plots containing this species, and mean defoliation of >10–25% on 60.4% of the plots, in total 72.3% for class 0 and 1 (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 1.8% 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 and western Bulgaria.

The 20-year trend in mean plot defoliation of Austrian pine shows an increase of 6.2% (Figure 6-2c). From 2010 to 2014 the annual mean plot defoliation was lower than the trend, but it has been above the trend line 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 2019, 71.4% 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 3.8% of plots had defoliation up to 10%. Defoliation was moderate on 27.7% 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 the trend shows an increase in defoliation of 6.9% over the past 20 years (highest increase of all assessed species or species groups), and this trend is highly significant like in all other conifer species or species groups (Figure 6-2d).

Common beech

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

In 2019, common beech had up to 10% mean defoliation on 20.9% of the beech plots, a bettering from the year before. Most of these plots were located in Romania, Bulgaria and Serbia (please refer to the online supplementary material[1], Figure S1-5). On 44.9% of the monitored plots, beech trees were slightly defoliated (>10–25% defoliation). There were 33.1% of plots with moderate mean defoliation (>25–60%), and 1.1% 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 20-year trend in mean plot defoliation of common beech shows a slight increase of 2.4% (Figure 6-2e). 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). The effect of the drought affecting some European regions in 2018 is not very prominent.

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 2019, mean defoliation of temperate oaks was up to 10% on 6.5% of the plots, and from >10 to 25% on 40.3%, giving less than half of the plots (46.8%) with none or slight mean defoliation. Moderate mean defoliation (>25–60% defoliation) was recorded on 52.3% of plots and severe defoliation (more than 60% defoliation) on 0.9% 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 an increase in mean plot defoliation (2.2%) 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 6-2f). The largest deviation of the mean defoliation from the trend line happened in 2019, possibly due to the effects of drought events both in 2018 and 2019 (JRC 2019).

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 2019, Mediterranean oaks had mean defoliation up to 10% on 16.1% of the plots, and on 49% of the plots between 10 and 25%, yielding a total of 65.1% of plots with mean defoliation up to 25% for these oaks. A third (34.5%) of plots showed moderate mean defoliation for Mediterranean oaks, and only 0.4% 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 trend in mean plot defoliation for deciduous (sub-) Mediterranean oaks for the past 20 years (Figure 6-2g). 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 only 1.6% of the plots mean defoliation of evergreen oaks was up to 10%, and on 46.1% of the plots from >10 to 25% defoliation. When combining class 0 and 1, less than half of the plots had mean defoliation of up to 25% (47.7%, please refer to the online supplementary material[1], Figure S1-8). Moderate defoliation was recorded on 50.6% 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 in Spain.

Based on the trend analysis, evergreen oaks have the second highest increase in defoliation over the last 20 years (6.9%, Figure 6-2h). 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 2019, damage cause assessments were carried out on 103 297 trees in 5 654 plots and 26 countries. On 50 446 trees (48.8%) 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 is reported. On 1 153 plots no damage was found on any tree.

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 number of recorded damage symptoms per assessed tree (ratio, Table 6-5) was higher for the broadleaved tree species and species groups than for the conifers. It was highest for evergreen oaks with 1.17 and lowest for Norway spruce with 0.41 symptoms per tree. Compared to 2018, both the numbers of recorded damage symptoms and the ratios have been increasing for all species and species groups, except for Scots pine.

Table 6-5: Number of damage symptoms, assessed trees and their ratio for the main tree species and species groups in 2019. Multiple damage symptoms per tree and dead trees are included.

Main species or species groups	N damage symptoms	N trees	Ratio
Scots pine (*Pinus sylvestris*)	9 428	17 626	0.53
Norway spruce (*Picea abies*)	4 790	11 794	0.41
Austrian pine (*Pinus nigra*)	3 162	5 305	0.60
Mediterranean lowland pines	5 422	8 382	0.65
Other conifers	4 139	7 817	0.53
Common beech (*Fagus sylvatica*)	9 423	11 212	0.84
Deciduous temperate oaks	8 723	8 434	1.03
Dec. (sub-) Mediterranean oaks	7 212	8 087	0.89
Evergreen oaks	5 396	4 604	1.17
Other broadleaves	14 816	20 036	0.74
Total			
Conifers	26 941	50 924	0.53
Broadleaves	45 570	52 373	0.87
All species	72 511	103 297	0.70

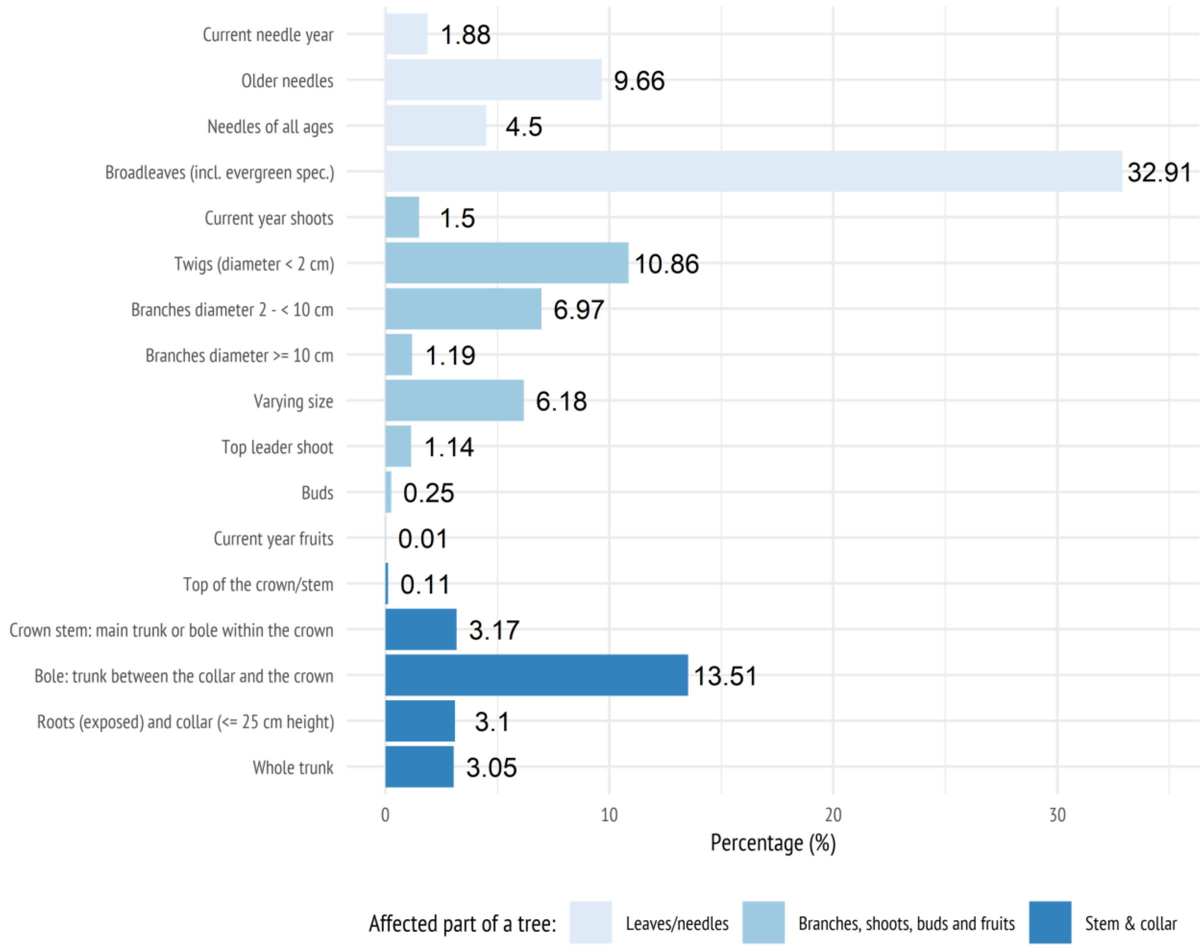


Figure 6-3: Percentage of recorded damage symptoms in 2019 (n=71 600), affecting different parts of a tree. Multiple affected parts per tree were possible. Dead trees are not included.

EVALUATIONS

Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (32.9%), followed by twigs and branches (25.2%), and stems (19.7%; Figure 6-3). Needles were also often affected (16.0%), while roots, collar, shoots, buds and fruits were less frequently affected.

More than half (52.9%) of all recorded damage symptoms had an extent of up to 10%, 38.5% 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 26.4% of all recorded damage symptoms (Figure 6-4). Almost half of the symptoms caused by insects were attributed to defoliators (48.1%), the most frequent of all specified damage causes. Wood borers were responsible for 15.6%, leaf miners for 12.1%, and gallmakers for 6.7% of the damage caused by insects.

Abiotic agents were the second major causal agent group responsible for 17.6% of all damage symptoms. Within this agent group, more than half of the symptoms (53.4%) were attributed to drought, while snow and ice caused 8.9%, wind 7.2%, and frost 3.8% of the symptoms.

The third major identified cause of tree damage were fungi with 10.7% of all damage symptoms. Of those, 22.5% showed signs of decay and root rot fungi, followed by dieback and canker fungi (15.9%), needle cast and needle rust fungi (12.2%), powdery mildew (11.5%) and blight (9.8%).

Direct action of man refers mainly to impacts of silvicultural operations, mechanical/vehicle damage, forest harvesting or resin tapping. This agent group accounted for 4.2% of all recorded damage symptoms. The damaging agent group 'Game and grazing' was of minor importance (1.2%). Fire caused 0.6% of all damage symptoms. The agent group 'Atmospheric pollutants' refers here only to incidents caused by local pollution sources. Visible symptoms of direct atmospheric pollution impact, however, were very rare (0.1% of all damage symptoms). Other causal agents were responsible for 9.4% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable number of symptoms (29.9%) could not be identified in the field.

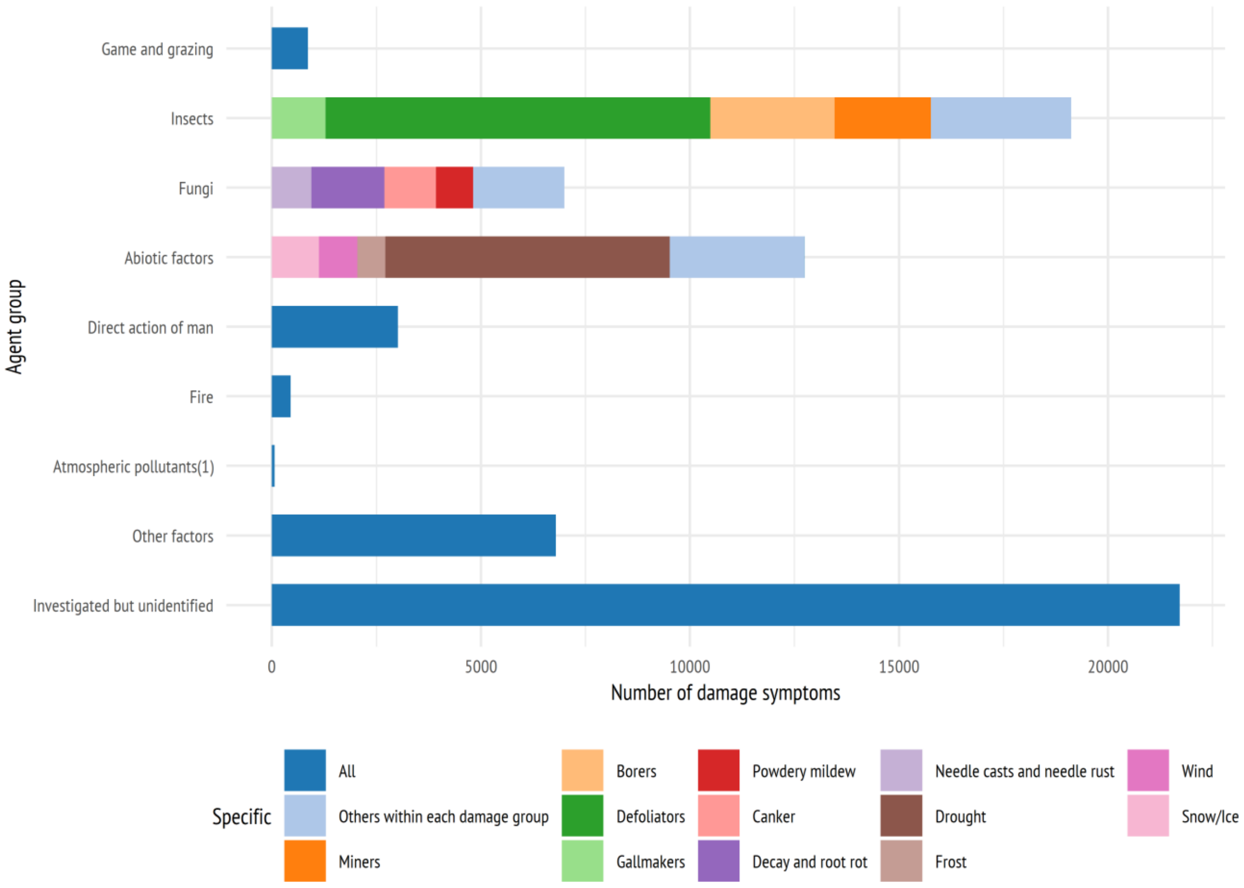


Figure 6-4: Number of damage symptoms (n=72 511) according to agent groups and specific agents/factors in 2019. Multiple damage symptoms per tree were possible, and dead trees are included. (1) Visible symptoms of direct atmospheric pollution impact only

The occurrence of damaging agent groups differed between major species or species groups (Figure 6-5). Insects were the most important damaging agent group for deciduous temperate oaks (causing 38.9% of all damage), common beech (37.5%), deciduous (sub-) Mediterranean oaks (34.4%), and Austrian pine (26.8%), while insect damage was not so common in Scots pine (11.4%) and Norway spruce (8.6%). Abiotic factors caused by far the most damage in evergreen oaks (44.8%) and Mediterranean lowland pines (43.8%). Fungi were important damaging agents for Austrian pine (19.4%), deciduous temperate oaks (14.9%), evergreen oaks (13.8%) and Scots pine (12.9%). Direct action of man was of little importance in general; it had the highest impact on Norway spruce (13.7%) and Scots pine (8.3%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (10.4%). Fire affected mostly Mediterranean conifer species – 1.1% of Austrian pine and 1.2% of Mediterranean lowland pine trees were affected. The percentage of recorded but unidentified damage symptoms was quite low in evergreen oaks (9.2%) but large for Norway spruce (43.0%), deciduous (sub-) Mediterranean oaks (34.7%), common beech (33.3%), and Scots pine (32.6%).

The most important specific damaging agents for common beech were mining insects (causing 19.6% of the damage symptoms), followed by defoliators (11.3%) and drought (3.7%). Defoliators were also frequently causing damage on deciduous temperate oaks (19.3%), while powdery mildew (8.6%), borers (5.7%), and drought (4.1%) also were significant. For deciduous (sub-) Mediterranean oaks, defoliators (14.1%) were the most common damaging agents, followed by borers (8.2%), gallmakers (6.6%) and drought (5.3%). Drought was by far the most important damaging agent for evergreen oaks (41.5%), but also borers (12.0%), decay and root rot fungi (9.4%) and defoliators (7.8%) had a large impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (13.0%), followed by *Viscum album* (7.5%) and defoliators (5.9%). For Norway spruce, borers (5.9%), red deer (5.6%) and mechanical/vehicle damage (5.0%) were most important. Defoliators were causing most damage (23.2 %) on Austrian pine trees, but *V. album* (12.7%), needle cast/needle rust fungi (10.9%), blight (6.9%) and drought (5.8%) also caused considerable damage. Mediterranean lowland pines were mostly affected by drought (35.4%) and defoliators (8.9%).

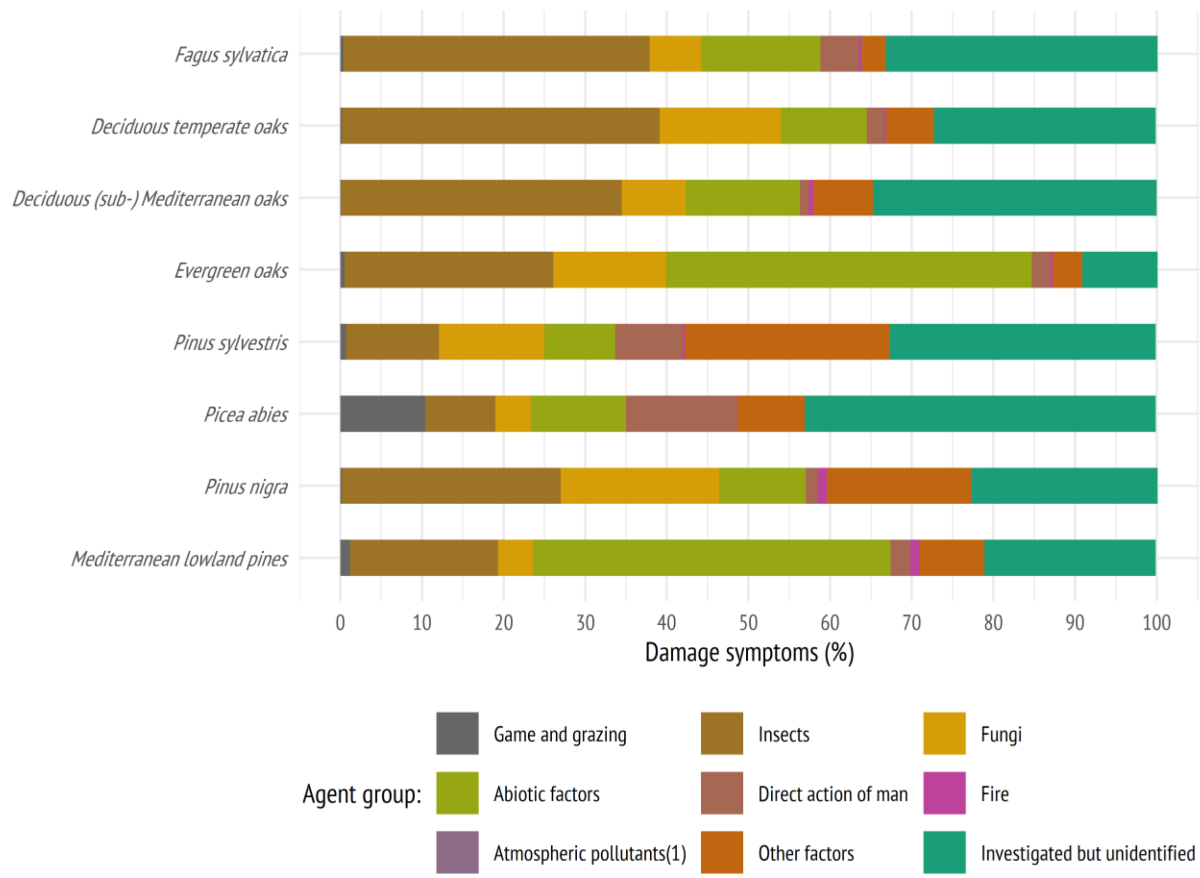


Figure 6-5: Percentage of damage symptoms by agent group for each main tree species and species group in 2019. (1) Visible symptoms of direct atmospheric pollution impact only

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Regional importance of the different agent groups

Damage caused by insects in 2019 was observed on 1 960 European Level I plots, which corresponds to 3.5% of all plots with damage assessments. With some exceptions (Scandinavia, northern Germany and the Baltic countries), a high proportion of plots was affected by insects throughout Europe.

Damage caused by abiotic agents was reported from 1 941 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 1 347 European Level I plots (24%) in 2019, 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' impacted trees on 1 024 plots (18%), and was most frequently occurring in southern Sweden, parts of eastern Europe and southern Germany.

Damage caused by game and grazing in 2019 was most frequently observed in the Baltic countries, Hungary and Spain, and in parts of Poland and Germany. In total, 288 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].

Tree mortality and its causes

There were 911 (0.9%) dead trees in the damage assessment 2019 (456 broadleaves and 455 conifers), an increase compared to 2018 (711 trees, 0.7%). The main cause of mortality to both conifer and broadleaved trees were abiotic factors (Figure 6-6). For the broadleaves, fungi and insects were also major causes of mortality, while for conifers, insects, fungi and fire were also of importance. A large part of the damaging agents causing tree mortality could not be identified with certainty.

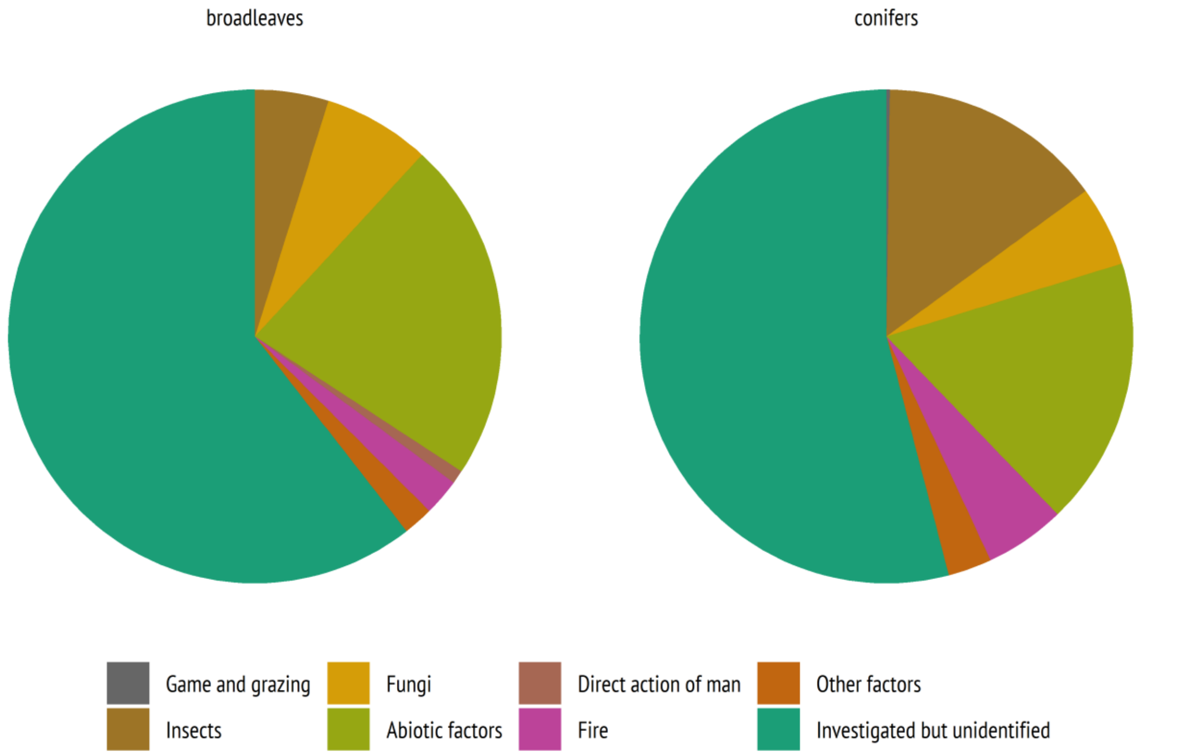

Figure 6-6: Percentage of damaging agent groups causing mortality of broadleaved and coniferous trees in 2019 (n = 911)

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

Conclusions

In 2019, the mean defoliation was somewhat higher than in 2018, increasing by 0.3% to 23.2% for broadleaved and by 0.9% to 22.2% for coniferous species. Out of all species and species groups, Mediterranean lowland pines and evergreen oaks had the largest increase in defoliation from 2018.

Based on the data of the past 20 years, the trends show a considerable increase in defoliation of Austrian pine, Mediterranean lowland pines and evergreen oaks (6.2%, 6.9% and 6.9%, respectively). On the other hand, the increase in defoliation for common beech (2.4%) and deciduous temperate oaks (2.2%) has been relatively low. The trends for Norway spruce and Scots pine show a moderate increase in defoliation of 3.2% and 4.2%, respectively. No trend was detected for deciduous (sub-) Mediterranean oaks.

As in previous years, the number of recorded damage symptoms per assessed tree was substantially higher for broadleaves than for conifers. Insects, abiotic causes and fungi were the most common damage agent groups for all species, comprising altogether more than half of all damage records. There was an increase in the number of observed damage symptoms compared to 2018, especially from drought. Also, tree mortality increased substantially in 2019, mainly caused by abiotic factors.

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7

ADDRESSING CHALLENGES ASSOCIATED WITH LONG-TERM FOREST ECOSYSTEM MONITORING

Manuel Nicolas, Alexa Michel

Introduction

ICP Forests has been a pioneering and successful initiative in transnational long-term forest ecosystem monitoring under the UNECE Air Convention since its establishment in 1985. Its design based on permanent monitoring plots has allowed the study of responses of forest ecosystems to environmental changes and to detect significant temporal and spatial trends. In the last years, however, the intensive (Level II) forest monitoring plots, which were established starting in 1994, have begun to face several practical challenges, and it has become widely acknowledged within the monitoring community that these need to be addressed to ensure a successful continuation of the programme. As the monitoring plots were installed in adult forest stands, many of the investigated stands have become old or disturbed and have started to regenerate or will need to be regenerated in the years to come. This will have a strong impact on the plots and the condition of the investigated ecosystems, and it may even impair the continuation of some survey types.

Unfortunately, the information collected on the design and management of the Level II plots has not been detailed enough in the past to meet these challenges, to evaluate their potential impacts, and to discuss ways to address them consistently at the international scale. To overcome this lack of information, a questionnaire was prepared and distributed to the National Focal Centres (NFCs), which represent the ICP Forests member countries, with the aim to receive feedback and discuss expectations and recommendations for action. This chapter presents the questionnaire's main results from a total of 35 respondents (30 countries and five German forest research institutes representing eight German Bundesländer) between 9 May and 25 June 2019. For a list of complete answers and comments, please refer to the online supplementary material.[1]

Main results from the questionnaire on the Level II monitoring

What are the challenges for the long-term practicability of the Level II monitoring network?

Four main challenges were identified and submitted to the NFCs for discussion:

- Stand regeneration: Should the monitoring activities be continued in the regeneration stage of forest stands, and how? Or should the concerned plots be relocated to other adult stands?
- Stand heterogeneity due to severe disturbances: Should data collection be continued on severely disturbed plots, e.g., to evaluate the effects of the disturbances and to get insight into the increased spatial variability, or to include additional stand development stages? Or should plots be replaced after severe disturbances?
- Biases due to monitoring activities: How can the long-term effects of monitoring activities on the monitored ecosystems be evaluated and how can potential biases be sufficiently minimized?
- Forest management practices: Can we assess and document management activities on the plots in order to distinguish their effects from those of environmental factors?

The majority of respondents considered all of these challenges as important or very important for the ICP Forests Level II network except for the challenge "Biases due to monitoring activities" which was rated a little less important (cf. Figure 7-1, Figure S3-2[1]). In general, the presented challenges are perceived as even more important for the international ICP Forests network than for national networks, which shows that some NFCs may worry about the overall consistency of the programme and data quality even if not feeling overly concerned at the national level.

How many countries have already faced such challenging situations?

Many countries have already faced such challenging situations and have been confronted with the resulting changes in plot condition (cf. Figure 7-2, Figure S3-3[1]):

- About half of the respondents have reported either increasing heterogeneity on Level II plots resulting from severe disturbances (more than 50% of the overstorey destroyed by e.g. wind, fire, or insects) and/or tree regeneration (with a juvenile stand established under or in place of the original adult one).
- A large majority (more than 70%) has reported that their plots are under active forest management, which is consistent with the initial requirement for no difference in the management of the plots and of their surroundings (EU

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

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1994), and with the fact that most of the European forest is under management (Forest Europe 2015). Among countries that have never had any plots under active forest management, some had made the explicit decision to install their plots in nature reserves. Others commented that active forest management has been excluded after plot installation to avoid damage to monitoring devices or because of the installation of a fence which makes access more difficult.

- As regard to potential biases due to monitoring activities, more than 60% of the respondents have had at least some of their plots fenced. Fencing can impact forest development in the plot as compared to its surroundings by e.g. excluding ungulates (Boulanger et al. 2018). But it is considered by 65% of the NFCs as useful or sometimes even necessary to prevent a destruction of monitoring devices (cf. Figure S3-8[1]).
- The majority of respondents (54%) who are in charge of the monitoring activities also have a direct influence on the definition of the forest management plans concerning their plots (cf. Figure S3-10[1]). This may be a source of bias as compared to regular management practices but it can also help to maintain and renew the stand according to specific monitoring interests (e.g. by defining the main targeted tree species to be regenerated and subsequently monitored).
- Finally, several respondents reported that they sometimes had to remove small trees, shrubs or deadwood to be able to conduct the monitoring activities (cf. Figures S3-11 and S3-12[1]), e.g. to keep the crown of sample trees visible, to (re-)install probes, or to create and maintain pathways.

How have countries so far addressed these challenging situations?

Only a minority (less than 25%) of the respondents have already defined specific rules to address the identified challenges (cf. Figure S3-4[1]). Nearly half of them have reported to have rules addressing the challenge "Forest management". But comments show in several cases that these include only the application of the same management practices in and surrounding the plot, and not the assessment of the management practices and an evaluation of their potential effects on ecosystem responses.

When a stand enters the regeneration stage either following overstorey removal or severe disturbances, some countries have decided to move the concerned plot to another location, while others have preferred to continue to monitor it at the same location. Survey protocols, however, have rarely been adapted yet by NFCs with the aim to collect data in juvenile and/or heterogeneous stands (cf. Figure S3-5[1]):

- Some of the respondents briefly reported changes in the plot area, in the number of replicates, in the sampled trees, or in the type of samplers or measurements, after plot disturbance, to stay in homogeneous conditions.
- Some indicated when and how they intend to resume surveys after felling.
- Very few reported existing documents about protocols adapted to juvenile and/or heterogeneous stands for at least some of the surveys.

How should the identified challenges be addressed by ICP Forests?

To address the two challenges about how to deal with stand regeneration and stand heterogeneity, two-thirds of the respondents would appreciate guidelines from ICP Forests with different options rather than maintain original requirements for stand conditions for Level II plots (cf. Figure 7-3, Figure S3-6[1]).

Indeed, for example, only 6 of the 35 respondents would agree to either relocate or continue to monitor their Level II plots when they enter the regeneration stage, if this would be required by ICP Forests to keep the international network consistent (cf. Figure 7-4, Figure S3-7[1]). As expected, there is no uniform agreement between NFCs about one best option to answer this specific question, because it depends a lot on national needs, strategy and funding resources. Some countries would prefer to continue the monitoring at the same location in order to capitalize on the value of the long time series already collected, to observe ecosystems in early stages of development, or because they have no means to establish new plots. Others would prefer to relocate plots because they cannot take the risk for the regeneration process to fail or wait for decades until all survey types can be resumed, or because the national demand is about the response of adult stands which constitute the largest part of forested areas. Doing both (which implies to increase the number of plots) would be an ideal option to evaluate the effects of the development stages in addition to those of environmental changes, but it appears too costly to most countries. Still this question of relocating or keeping monitoring plots after the end of a stand rotation remains under discussion in many countries. And, even if it is up to national capacities and strategies, comments also reveal some strong concern about the comparability of the data at the international scale, and an interest for international guidelines balancing advantages and disadvantages of each option, and for survey protocols adapted to juvenile and heterogeneous stands.

As regard to forest management history, it appears that consistent information about practices is available in 63% of the countries, at least since plot installation (cf. Figure 7-5, Figure S3-9[1]). In others (34%) only partial information is available. So there is an opportunity to document the stand history in the ICP Forests database, as a potential explanatory factor of the observed ecosystem responses.

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

Conclusions and followings

After 35 years of successful activity, the ICP Forests community has acknowledged important challenges to be addressed to successfully continue with the transnational intensive (Level II) long-term forest monitoring. However, the questionnaire also revealed certain contrasts in the initial choices in plot design and management in the different countries, and in their current priorities and available financial resources. In consequence, one-way decisions should not be made and imposed uniformly at the international scale, but recommendations and guidelines are nevertheless highly expected to keep consistency in applying each of several possible monitoring strategies.

As a result of the findings from this questionnaire, the latest update of the ICP Forests Manual adopted in 2020 included some first changes to the basic design principles of the Level II intensive forest monitoring (Part II) and to several specific survey protocols with the aim

- to present possible options on how to handle plots entering the regeneration stage and list their advantages and disadvantages with regard to strategical and practical considerations;
- to adapt survey protocols to the conditions of juvenile and/or heterogeneous stands;
- to better document the status of each plot (and its potential relocation), and the status of the forest stand (in the plot and in the buffer zone);
- to collect standardized information about the stand history (management practices and natural disturbances) since plot installation or even earlier if available.

Although further discussion will be needed to fully respond to the four identified challenges, the presented information and guidelines can be regarded as a first important step towards maintaining the value of the ICP Forests long-term monitoring system over time, with the aim to successfully continue the evaluation of the effects of air pollution, climate change and other natural and anthropogenic stressors on forest ecosystems throughout the UNECE region.

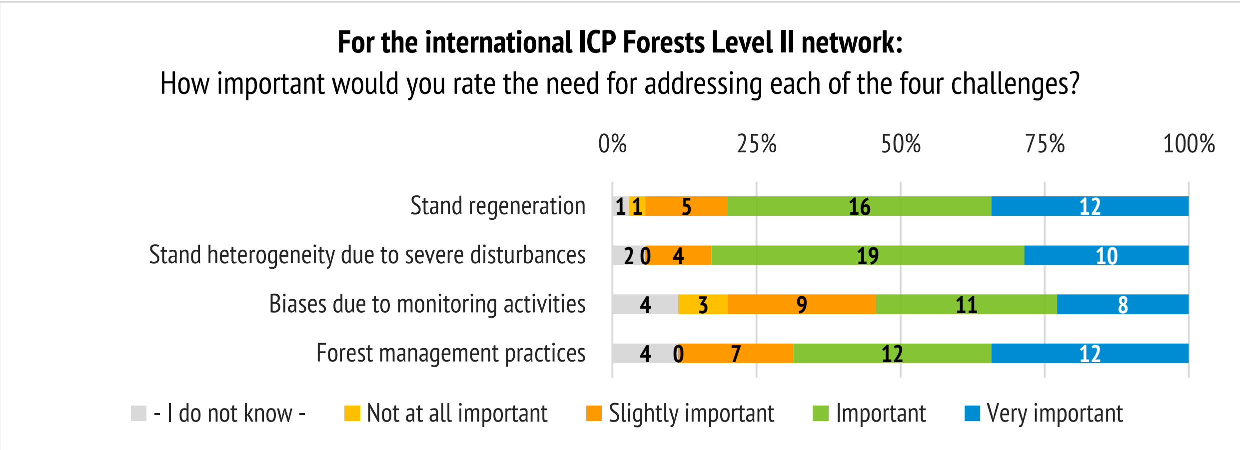

Figure 7-1: Rating of the importance of four challenges associated with long-term forest ecosystem monitoring (Questions 1, 2)

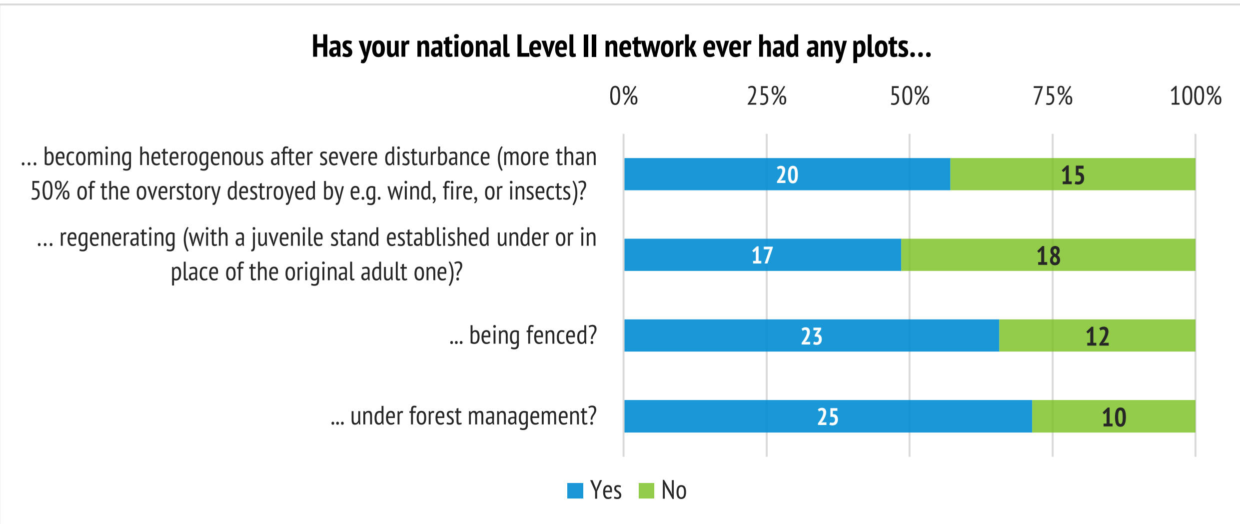

Figure 7-2: Level II plot management and experience with challenges (Question 3)

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

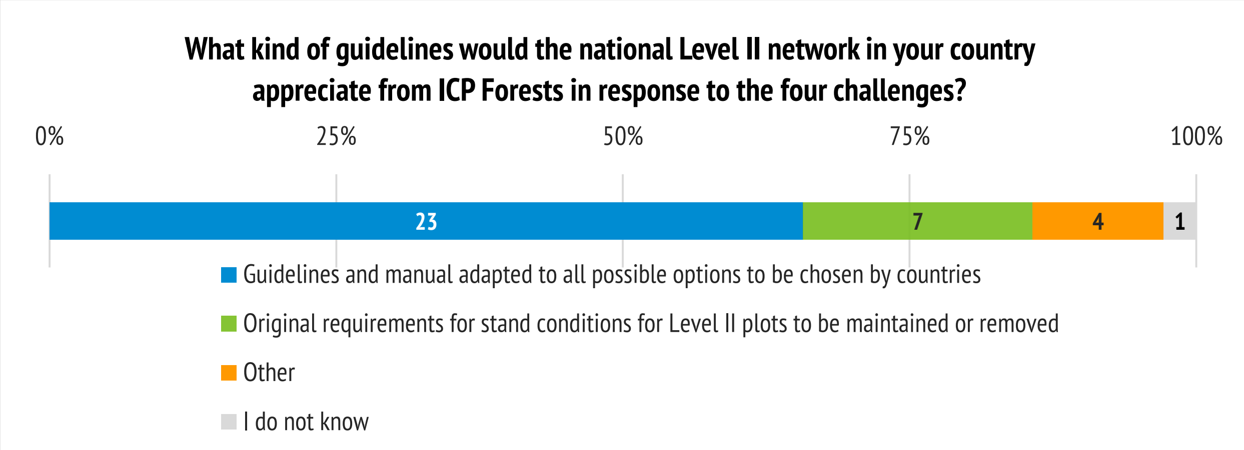

Figure 7-3: Requested guidelines on future Level II plot management addressing these challenges (Question 6)

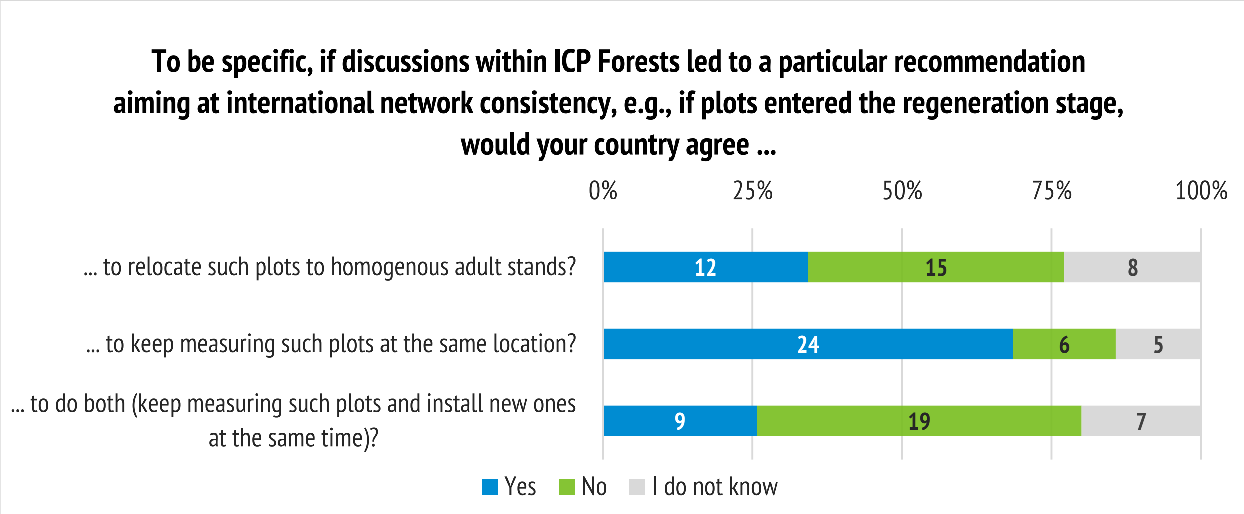

Figure 7-4: Potential acceptance of ICP Forests guidelines after stand disturbance and regeneration on Level II plots (Question 7)

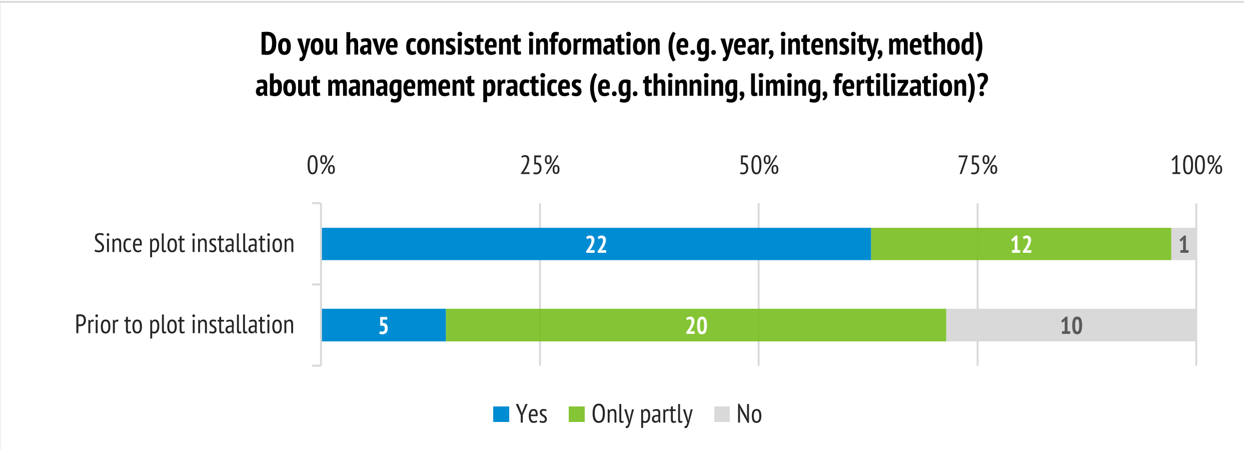

Figure 7-5: Availability of long-term information on management history of Level II plots (Questions 9, 10)

References

For all written responses to the questionnaire, please refer to the Online Supplementary Material[1].

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

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PART C

National reports of participating countries in ICP Forests

8 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.

Austria

National Focal Centre

Ferdinand Kristöfel, Austrian Research Centre for Forests (BFW)

Main activities/developments

Crown condition assessments on the Level I plots and on the Level II plots in Austria were already discontinued in 2011 and all 135 Austrian Level I plots were abandoned.

Monitoring activities on the 16 Austrian Level II plots are continued although with reduced extent. In 2019 on all 16 plots wet deposition was collected and analysed and the measurement of tree growth (diameter and tree height) within the five years interval was performed. Foliage samples were taken on all 16 plots. The samples are taken annually, in addition to the recommended biennial sampling in the manual, as the results from the Austrian Bioindikatorgrid (www.bioindikatornetz.at) revealed huge variations between individual years. On 6 out of the 16 Austrian Level II plots – Level II core plots – also meteorological measurements, including measurement of temperature and moisture of the soil, were continued as well as collection of litterfall, chemical analysis of soil solution and measurement of tree increment via mechanical and electronic girth bands.

Major results/highlights

In January 2019 two Level II plots (11-Mondsee, 17-Jochberg) were severely damaged by heavy snow breakage including damage of measurement devices. Sampling of deposition on these plots was not possible until spring.

The results of deposition analyses during the last 20 years over all plots indicate a decrease of sulphur input and an increase of nitrogen input.

The results of the measurements and the chemical analyses on the Austrian level II plots can be seen at:
www.waldmonitoring.at

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

In 2019 no remarkable publications referring to the Austrian monitoring plots.

Outlook

The monitoring activities on the 16 plots will be continued although on a low level.

The six core-monitoring plots are included in the network of sites for monitoring the negative impacts of air pollution upon ecosystems under the National Emissions Ceilings (NEC) Directive (2016/2284/EU). These plots will form the basis for collecting and reporting the information concerning forest ecosystems required under the NEC Directive.

Belgium Flanders

National Focal Centre

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

Main activities/developments

In Flanders, the Level I survey comprises 1474 trees on 71 plots, based on a 4x4 km grid. The sample consists of 55.4% broadleaves (n=816) and 44.6% conifers (n=658). The main species are *Pinus sylvestris* (n=488), *Quercus robur* (n=366), *Pinus nigra* subsp. *laricio* (n=163), *Fagus sylvatica* (n=123) and *Quercus rubra* (n=92). Less common species are gathered in the subsets 'other broadleaves' (14 species, n=235) and 'other conifers' (2 species, n=7). Examples of 'other broadleaved species' are *Castanea sativa*, *Quercus petraea*, *Alnus glutinosa*, *Fraxinus excelsior*, *Betula pendula*, *Acer pseudoplatanus* and *Populus* sp.

Major results/highlights

In 2019, mean defoliation was 24.4% and 22.7% of the trees were rated as damaged. Most of these trees revealed moderate defoliation (19.7%). 1.8% of the trees showed severe defoliation and 1.2% had died. 8.5% of the trees were registered as healthy. Mean defoliation was 22.7% in conifers and 25.7% in broadleaves. The share of trees in defoliation classes 2-4 was 26.8% in broadleaves and 17.6% in conifers.

The lowest level of damage was observed in *Pinus sylvestris* and *Fagus sylvatica*, with 14.7% of *P. sylvestris* and 21.1% of *Fagus sylvatica* classified as being damaged. Defoliation was higher in 'other broadleaves', *Q. rubra*, *Q. robur* and *Pinus nigra*. The share of trees rated as damaged was 29.8%, 28.3%, 26.4% and 26.4% respectively.

Weather circumstances improved compared to 2018 but were still not favorable. After storm damage in March and June, removals were executed in 15% of the plots. 1.6% of the sample trees were excluded from the survey. During summer, three heat waves occurred and temperature records were registered (max. T> 40 °C). Symptoms of drought were observed in several plots.

Crown condition deteriorated compared to last survey. The only species with a decrease in mean defoliation were *Fagus sylvatica* (-3.9 percentage points) and *P. nigra* (-2.1 percentage points). A significant increase was recorded in *Quercus rubra* (+4.9 percentage points) and *Q. robur* (+1.8 percentage points). *P. sylvestris* and the 'other broadleaves' showed a slight worsening of the crown condition (+0.9 percentage points).

Compared to 2018, the share of *Fagus sylvatica* and *Q. robur* with moderate to high fructification was low, 2.4% and 2.7% respectively.

More insect defoliation was detected, especially on *Q. robur*. 25.7% of the oak trees showed moderate to severe insect defoliation, caused by different species. Dry weather circumstances in 2018 favored the distribution of *Thaumetopoea processionea*. Caterpillar nests were registered on 7.9% of the *Q. robur* trees. The share of *Q. robur* plots with observations of *T. processionea* was the highest ever (32.3%).

Discolouration was common on broadleaves. 15.6% of the broadleaved trees showed discolouration on more than 10% of the leaves. Mildew infection (*Microsphaera alphitoides*) caused moderate to severe discolouration on 24.3% of *Quercus robur*.

Drought, storm and an increasing volume of dead and damaged trees favored populations of wood boring insects and this may lead to higher defoliation scores in the future. In Flanders, mortality of *Picea sp.* increased and in several forests *Pinus sylvestris* also revealed a bad condition. Although mean defoliation in *P. sylvestris* increased, a significant deterioration could not be assessed in the Level I plots.

A survey on the health status of *Fraxinus excelsior* and the impact of *Hymenoscyphus fraxineus* started in 2014. 252 ash trees were selected on a total of 29 plots, including 9 Level I plots. In this survey a deterioration of the crown condition was observed. Mean defoliation increased from 28.8% in 2014 to 47.9% in 2019. The share of trees showing more than 25% defoliation was 32.1% in 2014 and 55.6% in the last survey. In 2019 32.1% of the trees showed more than 60% defoliation. Since the start of this survey, 16.3% of the sample trees died.

A poster on the variability of ozone deposition velocity over a mixed suburban temperate forest (*Pinus sylvestris* L.) at a Level II plot in Brasschaat was presented at the 32nd Task Force Meeting of the UNECE ICP Vegetation, Targoviste, Romania. A dissolution experiment was carried out in our laboratory with the aim to study the role of pollen on throughfall biochemistry.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Neirynck J, Verstraeten A (2019) Ozone deposition over a mixed suburban forest. Poster presented at the 32nd Task Force Meeting of the UNECE ICP Vegetation, Targoviste, Romania https://pureportal.inbo.be/portal/files/16076520/Neirynck_Verstraeten_Poster_ICP_Veg_Targoviste_2019.pdf

Sioen G, Verschelde P, Roskams P (2019) Bosvitaliteitsinventaris 2018. Results of the crown condition survey (Level I). Research Institute for Nature and Forest, Report 2019 (20). INBO, Brussels (in Dutch). ISSN: 1782-9054,DOI:doi.org/10.21436/inbor.16207115 https://pureportal.inbo.be/portal/files/16328536/Sioen_Verschelde_Roskams_2019_Bosvitaliteitsinventaris2018ResultatenUitHetBosvitaliteitsmeetnetLevel1.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*.

Belgium Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2019, data were collected in eight plots for Level II/III and in 47 plots for Level I. Five larch plots were added.

Major results/highlights

The species began their growing season at normal dates, except for Douglas-fir which had a late budburst, and for spruce and hornbeam which had early budburst. As in 2018, the spring climate was favorable for trees but they had to face a severe drought during the summer. Climatic trends have normalized in the autumn. The development of insects was favored. More particularly, here are some tendencies for the following species:

- Spruce and Douglas-fir had to face serious insect damage, respectively by *Ips typographus* and by *Contarinia pseudotsugae*. Some spruce stands of the network had to be cut down. The drought of those last years had a negative effect, too.
- The degraded status of beech is maintained.
- The average defoliation of oak is slightly increasing. Spring damage due to defoliating caterpillars is increasing, too. *Thaumetopoea processionea* has been identified in many places in Wallonia but not yet in the network.
- Larch has been added to the network. Their average defoliation reaches 40%.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

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.

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 2019 observation covered 2391 coniferous trees, representing the four main coniferous tree species – *Abies alba* Mill., *Pinus nigra* Arn., *Picea abies* (L.) Karst and *Pinus sylvestris* L. and 3170 deciduous trees, representing nine of the main deciduous tree species in the country, including *Fagus sylvatica* L., *Fagus orientalis* Lipsky, *Quercus cerris* L., *Quercus frainetto* Ten., *Quercus petraea* (Matt.) Liebl., *Quercus rubra* L., *Carpinus betulus* L., *Castanea sativa* Mill. and *Tilia platyphyllos* Scop., or 5591 sample trees in total.

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). Monitoring activities are carried out in collaboration with Forest Research Institute – BAS and University of Forestry.

Major results/highlights

The results regarding the 'defoliation' criteria showed that in 2019 coniferous and deciduous trees were in the same condition as in 2018. Out of all the observed trees 68.9% were in classes 0 and 1 (no or little defoliation). The number of threatened and dried/dead trees from classes 3 and 4 showed an increase of 1.3%. Better condition was observed among 79.7% of the deciduous trees in the classes 0 and 1 and among 54.0% of coniferous trees. The percentage of class 4 (dead trees) was 1.5% of the deciduous and 3.9% of the coniferous trees sampled.

Among all the observed coniferous tree species in 2019, the number of healthy and slightly-defoliated trees (classes 0 and 1) remained the same in relation to the previous year and there was a rise in the proportion of severely-defoliated and dead trees (class 3 and 4) - from 10.2% in 2018 to 14.4%. The invasive pathogens *Lecanostica acicula* and *Dosthistroma septosporum* discovered in Bulgaria and considered to be highly-adaptable to new hosts and environmental factors, pose a threat to Scots pine (*Pinus sylvestris*) and Austrian pine (*Pinus nigra*) trees.

A high percentage of damage from wet snow was also detected in the coniferous tree plantations which may lead to widespread outbreaks of xylophagous insects.

In the common beech (*Fagus sylvatica*) stands slight damages were observed on the leaves caused by leaf-feeding, leaf-mining insects (*Orhestres fagi*, *Stigmella hemargyrella*) and gall-making insects. Small attacks by sucking insects (*Phyllaphis fagi*) were also recorded.

In the oak plots (*Quercus cerris*, *Q. frainetto*, *Q. petraea* and *Q. rubra*) damages caused by moths from Tortricidae and Geometridae were low.

As a whole, in the observed plots, widespread attacks by harmful insects and fungal diseases were not observed.

Observations in the sample plots for intensive monitoring (Level II) were focused on the effects of different stress factors and the ecosystem response. The results of the analysis and the evaluation carried out in 2018 showed the following:

Stress factors

In some years, ozone has been a stress factor in the spruce-fir plantation in the 'Yundola' and 'Rozhen' sample plots. Regardless of the fact that for the last two years the AOT40 for the protection of vegetation and forests has decreased, on average for a five-year period the short-term respective norm for vegetation protection was exceeded 1.4 times and that for forest protection 2.7 times. The calculated values for AOT40 at the 'Rozhen' sample plot in 2018 and 2019 also exceeded the level for forest protection and the short-term target norm for vegetation protection.

In 2017 and 2018, the average pH value of precipitation in the beech stand from the 'Vitinya' region was acidic. In the acidic ions group, the amount of chloride deposits increased. There were more calcium deposits from the basic ions group and more from the heavy metals: Cu, Pb, Cd and Al. In the 'Staro Oryahovo' site, the precipitation showed an acidic reaction. In 2018, there were larger quantities of nitrate nitrogen, ammonium nitrogen, sulphates and phosphates, base ions – Ca and Na and heavy metals deposited in the region. In the open field of the Yundola site, there was a registered increase, compared to 2017, in the deposition of ions with acidic functions, such as sulphates, nitrates and chlorides, as well as magnesium and calcium base ions and heavy metals: Pb and Fe.

Biological condition

Healthy and slightly-damaged trees dominated in the beech stand in the 'Vitinya' sample plot. Widespread pest and fungal attacks were not observed. In the 'Staro Oryahovo' sample plot, the number of healthy trees increased and the slightly- and severely-damaged trees decreased. In future, the spread of the semi-parasitic mistletoe (*Loranthus europaeus* Jacq.) may contribute to considerable damages. The mixed fir-spruce plantation at the 'Yundola' site was in good condition. A threat to the health of the plantation may prove to be the honey fungus (*Armillaria mellea*), which has been found on tree stumps in the form of rhizomorphs. In comparison with the observations in 2015, 2016 and 2017 there has been a reduction in the number of healthy trees at the 'Rozhen' sample plot.

Chemical analyses of leave/needle samples showed that in relation to regional thresholds, the elements that dominated were those whose values are categorized as 'adequate' for the normal functioning of beech and Hungarian oak. The nutritional status was balanced. It is possible for a feeding disequilibrium to appear in the spruce-fir plantation at the 'Yundola' sample plot.

The duration of the vegetation period in the observed beech stand at the Vitinya site in 2018 was 182 days on average. In 2017, by comparison, the duration was reduced by 20 days.

Chemical condition

Monitoring data for the Vitinya sample plot confirmed the mobility of water-soluble forms of the tested macro and micro-elements, as well as that of salts. The values of all tested indicators were low, while the processes in existence have led to nutrient loss in the soil. A trend for the large presence of manganese in soil solution was confirmed. The reaction of the litterfall remains in the acidic spectrum. The amount of nitrogen varies, but remains above minimal levels in the beech forests. There is an increased amount of microelements that is connected to the very strongly-acidic reaction of the soil solution.

In 2018, at the 'Staro Oryahovo' plot the pH results of the leaf mass fraction were some of the lowest. A higher concentration of zinc was found.

At the 'Yundola' sample plot the pH values of the different fractions of litterfall were very stable in the period 2010–2018. The content of sulphur varied significantly, while phosphorus, calcium, manganese and potassium were characterized by stable values.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Georgieva M, D Nedjalkov, G Georgiev, M Matova, G Zaemdzhikova, P Petkov, P Mirchev (2019) Monitoring of health status of Quercus cerris L. in the Eastern Balkan Range, and the Ludogorie (Bulgaria). In: Annual of Sofia University 'St. Kliment Ohridski' Faculty of Biology, Book 4 - Scientific Sessions of the Faculty of Biology, v. 104, 154-165. ISSN 2682–9851.

Georgieva M, G Georgiev, P Mirchev, E Filipova, G Zaemdzhikova (2019) Main pathogens and insect pests established on Castanea sativa Mill. stands in Belasitsa mountain. In: Proceeding papers 150 Years of Bulgarian Academy of Sciences, 'Professor Marin Drinov' Academic Publishing House, 55-64. ISBN: 978-619-245-001-4. ISBN 978-619-245-002-1 (Online)

Georgieva M, G Georgiev, P Petkov, G Zaemdzhikova, M Matova, E Filipova, P Mirchev (2019) Health status of beech (Fagus sylvatica) forests in Bulgaria in the period 2009-2018. Forest Science 2:95-104. ISSN 0861-007X (In Bulgarian, English summary)

Georgieva M, G Georgiev, P Mirchev, E Filipova (2019) Monitoring on appearance and spread of harmful invasive pathogens and pests in Belasitsa Mountain. In: Proceeding papers 'X International Agriculture Symposium AGROSYM 2019', 3-6 October 2019, Jahorina, Bosnia and Herzegovina. 1887-1892. ISBN 978-99976-787-2-0

Georgieva M, P Mirchev, G Georgiev, G Zaemdzhikova, M Matova, E Filipova, P Petkov (2019) Health status of pine stands observed in the extensive monitoring network in Bulgaria In: Proceeding papers 'X International Agriculture Symposium AGROSYM 2019', 3-6 Oct 2019, Jahorina, Bosnia and Herzegovina. 1893-1900. ISBN 978-99976-787-2-0

Dimitrov S, G Georgiev, P Mirchev, M Georgieva, M Iliev, D Doychev, S Bencheva, G Zaemdzhikova, N Zaphirov (2019) Integrated model of application of remote sensing and field investigations for sanitary status assessment of forest stands in two reserves in West Balkan Range, Bulgaria. In: Proceeding of SPIE 11174, Seventh International Conference on Remote Sensing and Geoinformation of the Environment

(RSCy2019), 1117404 (27 June 2019); doi: 10.1117/12.2532313

Kuzmanova R, E Pavlova, M Doncheva-Boneva (2019) Macro and Microelements Composition of Needles of Norway Spruce (*Picea abies* L. Karst.) and Silver Fir (*Abies alba* Mill.). Journal of Balkan Ecology 22(2). ISBN 978-954-749-116-8

Pavlova E, D Pavlov, M Doncheva, S Bencheva, D Doychev, I Koleva-Lisama R Kusmanova, G Kadinov, G Popova, V Radkov (2019) Forest Ecosystem Monitoring. Biological indikators. Region Strandja, of. 158 p. ISBN 978-954-749-116-8

Pavlov D (2019) Fluctuations of Ground Vegetation in Beech Forest of Vitinya Stationary Location, Western Stara Mountain, Bulgaria – Journal of Balkan Ecology 22(2). ISBN 978-954-749-116-8

Pavlova, E., D. Pavlov. 2019. Near-ground Phytomass and Evaluation of Nutrients Supply for Vegetation in Vitinya, Staro Oryahovo and Yundola Forest Monitoring Stations, Bulgaria- Journal of Balkan Ecology 22(2). ISBN 978-954-749-116-8

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 process of a gradual extension of the Level II network is in progress.

Croatia

National Focal Centre

Nenad Potočić, Croatian Forest Research Institute

Main activities/developments

NFC Croatia representatives participated in several ICP Forests meetings:

- Joint EP Meeting on Crown Condition, Soil & Soil Solution, Foliage and Litterfall, Deposition and QA/QC in Labs, Brussels;
- 35th Task Force Meeting of ICP Forests and 8th ICP Forests Scientific Conference, Ankara, Turkey;
- International Cross-Comparison Course Crown Condition (Central and Northern Europe), Chorin, Germany;
- 7th Meeting of the Heads of the Laboratories, Brasov, Romania;
- PCG meeting, Berlin, Germany;
- Workshop on Regional Impact Assessment of Atmospheric Deposition and Air Pollution on Forest Ecosystems, Niigata, Japan.

Major results/highlights

Level I

Ninety-seven sample plots (2328 trees) on the 16 x 16 km grid network were included in the survey 2019 - 1990 broadleaved trees and 338 conifers.

The percentage of trees of all species within classes 2-4 is relatively stable through the years - in the year 2019 it was 30.3%. Traditionally broadleaves have lower defoliation; in 2019 the percentage of broadleaved trees within classes 2-4 was 26.3%, while it was 53.6% for conifers. There is more variation in conifers also: the annual differences are usually up to 5 percent, in 2019 the difference to 2018 was as much as 6.5% more.

Most defoliated tree species in Croatia in 2019 were *Pinus nigra* (61.2%), *Fraxinus angustifolia* (58.2 %) and *Abies alba* (58.9% of trees in classes 2-4). The crown condition of narrow-leaved ash deteriorates constantly: from 8.6% in 2008 to 75.0% in 2017. In 2018, however, a small improvement was recorded which was continued into 2019, which is mainly the result of substituting dead trees in the sample – from 2017 onwards we record increased mortality of ash trees. Along with dry years (2017), and a long-time presence of *Stereonychus fraxini*, also the increased presence of *Hymenoschyphus fraxineus* (*Chalara fraxinea*) is a factor causing increased deterioration of ash health.

The largest number of damages was recorded on leaves (37.2% of all recorded damage), followed by branches, shoots and buds (35.4%), and finally on the trunk and butt end (27.5%). Most of the tree damage is caused by insects (27.2% of all damage), especially defoliators (13.6%). Next are abiotic agents with 12.3% of all damage. In 2019 drought was not a major damage factor. Damage caused by fungi accounted for 6.7% of all damages, while direct human activity accounted for 4.8% of all damage to forest trees. Most damages (66.6%) fall into the extent category 1 (0-10%).

Level II

Monitoring at the Level II plot 105 (Zavižan) was supplemented with phenological observations, and the plot was equipped with a set of suction cup lysimeters. A LESS for monitoring of ozone injury was set up nearby. First results are expected in 2020.

Crown condition on our intensive monitoring plots depends a lot on biotic factors: defoliators caused damage on all trees on plot 108; significant damage from beech leaf-mining weevil – *Rhynchaenus fagi* was recorded on plots 103 and 105; and needle necrosis caused by *Lophodermium* sp. fungi was recorded on about a third of Aleppo pine trees on plot 111. A grave problem for our pedunculate oak stands is *Corythuca arcuate* - damage in the form of leaf necrosis as the consequence of oak lace bug attack was found on all trees on plots 109 and 110.

Symptoms suggesting oxidative stress caused by high ground-level ozone concentrations were not found in 2019, despite high ozone concentrations in the air. It seems that ozone injury on our plots is linked to a specific combination of air temperature and precipitation.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Potočić N, Seletković I, Jakovljević T, Marjanović H, Indir K, Medak J, Anić M, Zorić N, Ognjenović M (2019) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2018. godinu. The damage status of forest ecosystems in Croatia – a report for 2018. Hrvatski šumarski institut/Croatian Forest Research Institute. Jastrebarsko, Croatia. www.icp.sumins.hr

Outlook

Setting up of deposition collectors and permanent growth bands on Level II plot 105 is under way.

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

Cyprus

National Focal Centre

Constantinos Nikolaou, Soteres Soteriou, Konstantinos Rovanias, Silviculture, Management and Publicity Sector – Research Section, Department of Forests

Main activities/developments

General Information

Cyprus is participating in the ICP Forests Programme since 2001. The systematic network of 19 permanent plots which has been established in Cyprus State Forests, is aiming at the collection of the necessary data, relevant to:

- Visual assessment of the forest crown condition
- Sampling and analysis of forest soil
- Sampling and analysis of forest soil solution
- Sampling and analysis of needles and leaves of forest trees
- Estimation of growth and yield of forest stands
- Sampling and chemical analysis of deposition (precipitation, snow, hail)
- Meteorological observations
- Assessment of forest ground vegetation
- Monitoring of air quality and assessment of ozone injury on forests.

These plots are divided in two categories according to the type of observations to be done and data to be collected:

- Systematic large-scale monitoring plots

  Fifteen plots, covering an area of 0.1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*), Black pine (*Pinus nigra*), and Cyprus cedar (*Cedrus brevifolia*) ecosystems. In these plots, annual observations of crown condition and periodic sampling and analysis of soil and needles are carried out.
- Intensive monitoring plots

  Four plots, covering an area of 1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*) and Black pine (*Pinus nigra*) ecosystems. In two of these plots, all research activities, mentioned above, are carried out. These plots are equiped with appropriate instruments and equipment for the collection of samples, data and information. The other two plots are partially equipped and only some research activities are carried out.

Cooperation and Submission of Data and Results

There is a close cooperation of the Cyprus Department of Forests and the ICP Forests Programme Co-ordinating Centre (PCC) in Eberswalde. There is also cooperation with Expert Panels which are responsible for the scientific work of the program.

For the implementation of the program, collaboration has been developed among the Department of Forests and other governmental departments such as the Department of Agriculture, Department of Labor Inspection and Meteorological Service. Until 2019, the laboratory part of the program (chemical analysis of water, soil solution, needles and soil) had been undertaken by the Department of Agriculture. The 2019 chemical analysis of needles and the 2020 chemical analysis of soil is undertaken by the Cyprus Agricultural Research Institute, while there is a possibility to collaborate with another organization for water and soil solution chemical analysis. Furthermore, there is exchange of information between the National Focal Centre and the Department of Labor Inspection, which runs the program "Network on Assessing Atmospheric Air-Quality in Cyprus". The Meteorological Service contributes to the program with technical support and maintenance of the Automatic Weather Stations.

Processing and submission of the relevant data is under the responsibility of the Cyprus Department of Forests.

Major results/highlights

Using ICP Forests findings, along with the expertise and long experience of the scientific personnel of the department, the Department of Forests adopts and applies mostly repeated actions which are designed to adapt on forest stands (natural and artificial), to face climate change. Also the objective of these actions is the reduction of emissions and the increase of the absorption of greenhouse gases. These actions can be grouped into three main areas as listed in the Statement of Forest Policy:

- Protecting forests against forest fires
- Adaptation of forests to climate change and enhancing the contribution of forests in addressing climate change and improvement of main forests and forested areas
- Improvement and expansion of forests.

Such measures are:

- Protection of forests from illegal logging: With the implementation of Law 139 (I) / 2013 is controlled most the available firewood locally and criminal penalties for any illegal or uncontrolled logging and/or disposal of the local timber market without authorization
- Reforestation of Amiantos asbestos Mine as well as restoration of abandoned mines in cooperation with the Competent Authorities (the Department of Geological Survey and the Mines Service)
- Protection of forests and enhancement of their structure and resistance to climate change through the Rural Development Program 2014 – 2020.

In particular, in the Rural Development Program, a number of activities and actions have been integrated under Measure 8 (Investments in forest area development and improvement of the viability of forests). The Action 8.5.3 includes thinning operations in thick stands created by afforestation / reforestation, with the purpose of:

Improving the structure of forests created by afforestation or/and reforestation operations. Furthermore, they will help in the adaptation of forest stands in climate change as well as contribute to the adaptation of forest stands to climate change, the reduction of emissions and increase the absorption of greenhouse gases.

The implementation of targeted thinning is expected to improve stability and resilience to other disturbances, such as drought, increase in average temperatures and prolonged heat waves (as a result of climate change).

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Until now, no publications/reports have been published with regard to ICP Forests data and/or plots.

Outlook

- The Cyprus Department of Forests will continue to participate in the ICP Forest programme under the current regime.
- Allthough not falling under the ICP Forests targets, the Cyprus Department of Forests is running a number of research projects such as on biomass production and the investigation of different techniques in order to reduce the irrigation rate in new plantations during the summer period.

Denmark

National Focal Centre

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

Main activities/developments

- Forest monitoring (Level II, Level I and NFI plots), including special focus on the consequences of the drought in 2018.
- Laboratory analysis methods have been thoroughly evaluated and several methods have been changed, especially regarding the use of ICP-MS and digestion using microwave oven.
- Resubmission of all Danish crown condition data and biotic/abiotic damage data from 1989 onwards, will continue in 2020.

Denmark participated in:

- The international Photo-Cross-Comparison Course 2019 (Photo ICC 2019) for the regions North and Central Europe.
- Joint EP Meeting on Crown Condition, Soil & Soil Solution, Foliage and Litterfall, Deposition and QA/QC in Labs (Brussels, Belgium), March 2019
- 8^{th} ICP Forests Scientific Conference (Ankara, Turkey), June 2019
- 7^{th} Meeting of the Heads of the Laboratories (Brasov, Romania), September 2019
- Presenting data findings from Danish ICP Forests sites at ILTER Open Science Meeting (Leipzig, Germany), September 2019

Major results/highlights

The national crown condition survey showed increased defoliation for most species, mainly due to the drought in 2018 combined with heaving fruiting in beech and spruce. The average defoliation of beech (*Fagus sylvatica*) was the highest recorded in Denmark and similar to the mid-1990s, where we had several dry summers. As expected, Norway spruce (*Picea abies*) had increased defoliation, compared to previous years, due to extensive shedding of needles in the autumn and winter of 2018. Our ash dieback monitoring plots had deteriorating health and increased mortality in 2019, probably as an effect of the drought in 2018 combined with optimal infection conditions in the wet summer of 2017.

The growth season 2019 was mainly warm and dry, but not as extreme as 2018, and there were several instances of cloudbursts with torrential rain. However, autumn 2019 was the wettest recorded since 1874, and this caused the yearly average precipitation to reach the record levels of 1999. Experience has shown that such weather extremes are detrimental to forest health in Denmark, mainly due to fluctuating soil water levels and other physiological stress factors.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Thomsen, IM, Jørgensen, BB, Callesen, I, Vesterdal, L, Ravn, HP, Hansen, JK, Kjær, ED, Nord-Larsen, T, Larsen, KS, Johannsen, VK & Ibrom, A (2019) Vedr. vurdering af 2018-tørkens indflydelse på skovbruget - opdatering vinter 2018/2019. [Concerning the evaluation of the 2018 drought's effect on forestry - updated winter 2018/2019] Institut for Geovidenskab og Naturforvaltning, Københavns Universitet, Frederiksberg 18 p. In Danish. https://static-curis.ku.dk/portal/files/213501856/Sagsnotat_toerke2018_v20190117.pdf

Nord-Larsen, T, Johannsen, VK, Riis-Nielsen, T, Thomsen, IM & Jørgensen, BB (2020) Skovstatistik 2018: Forest statistics 2018. 2 editon, Institut for Geovidenskab og Naturforvaltning, Københavns Universitet, Frederiksberg. https://static-curis.ku.dk/portal/files/237702036/Skovstatistik_2018_2_udgave_web.pdf

Outlook

- Future developments of the ICP Forests infrastructure: possibilities for implementing measurements of ambient air quality (especially regarding N and S), updated LAI measurements and remote sensing are being explored.
- Continued cooperation with LTER regarding the use of the Danish ICP Forests sites.
- Regarding the Danish evaluation and change of laboratory methods, we are in the process of preparing a presentation of our findings for the next meeting of the heads of labs.
- Planned research projects: Level I plots were resampled in 2018-19 as part of large national forest soil inventory of soil C stock changes since 1990. Samples are analysed for C and N, but soils are archived for further analyses in other projects.

Estonia

National Focal Centre

Estonian Environment Agency

Main activities/developments

The health status of 2636 trees was assessed on the observation points of the Level I forest monitoring network and on the sample plots of the intensive forest monitoring (Level II). 1683 trees were Scots pines (*Pinus sylvestris*), 679 Norway spruces (*Picea abies*) and 274 deciduous species, mainly Silver birch (*Betula pendula*). The observation period lasted from July 16 to November 8, 2019.

On Level II the following forest monitoring activities were carried out in 2019:

- chemical analyses of the deposition water collected throughout the year on 6 sample plots;
- chemical analyses of soil solution collected during 8 months (from March to October) on 5 sample plots;
- analyses of litterfall were collected on one plot according to ICP Forests requirements;
- foliar samples were collected in December;
- assessment of ground vegetation was carried out on all Level II plots;
- assessment of the growth of trees was carried out on all Level II plots.

Major results/highlights

Level I

The total share of not defoliated trees, 49.7%, was 0.9% lower than in 2018. The share of not defoliated conifers, 49.3%, was lower than the share of not defoliated broadleaves, 53.3%, in 2019.

The share of trees in classes 2 to 4, moderately defoliated to dead, was 5.8% in 2019 and 6.4% in 2018. The share of conifers and broadleaves in defoliation classes 2 to 4 was 5.9% and 4.7% accordingly.

The share of not defoliated pines (defoliation class 0) was 47.6% in 2019, 1.8% higher than in 2018. The share of pines in classes 2 to 4, moderately defoliated to dead, was 2.0%, lower than in 2018. The defoliation of Scots pine has improved in 2019.

However, the long-term trend of Scots pine defoliation shows no significant changes since 2010.

A long-term increase of defoliation of Norway spruce may be observed. The share of not defoliated trees (defoliation class 0) was 64.2% in 2010 and 53.6% in 2019. The share of not defoliated trees was higher in younger stands with the age up to 60 years (76.2%) than in older stands (38.2%).

Compared to the last several years there has been a significant decrease in the condition of broadleaves during 2015 and 2016. The defoliation of broadleaves improved in 2018 and has not changed in 2019. Compared to 2016 the defoliation of silver birches has improved 11.8% in 2019. The share of not defoliated silver birches was 59.8% in 2019 and 59.6% in 2018.

Numerous factors determine the condition of forests. Climatic factors, diseases and insect damages 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 2019, 3.3% of the trees observed had some insect damages, and 16.9% had symptoms of fungi (mainly Scots pines). Overall 38% of trees had no identifiable 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 11.4% of the observed pine trees in 2019, compared to 17% in 2018. Norway spruces mostly suffered due to old moose damages and root rot (pathogen *Heterobasidion parviporum*) – characteristic symptoms of root rot were observed on 4.5% of the sample trees.

No substantial storm damages and forest fires occurred in 2019.

Level II

The annual average pH of the precipitation under throughfall was varying mainly between 5 and 6. In 2019 observations showed some slight increase of pH compared to 2018. The content of chemical elements and compounds in analysed precipitation water was low. Generally the amount of precipitation in 2019 was higher than in 2018.

The pH of the soil solution varied between 3.8 and 6.3 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 $mg \cdot l^{-1}$. In 2019, similarly to the past years, the content of Ca^{2+}, K^{+} and Cl^{-} in soil solution was considerably higher than 2.5 $mg \cdot l^{-1}$ on all spruce sample plots. The concentration of Mg^{2+}, Na^{+} and SO_4-S in the spruce stand at Karepa was essentially higher than the level of 2.5 $mg \cdot l^{-1}$.

The results of litterfall collected in 2018 did not show any significant trends of diferent elements. Rather higher values of lead (Pb) could be detected in the non-foliar litter fraction of litterfall during the observation years.

Foliar analyses of 30 sample trees were collected in December 2019.

The assessments of ground vegetation and of the growth of trees take place every five years. The increment of trees compared to the NFI was detected to be above average on all plots, except at Sagadi and Vihula. The cover and number of the different species in the layers of ground vegetation has been improved during the past five years.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

FOREST MONITORING, Report of the survey 2019. Vladislav Apuhtin, Tiiu Timmusk, Heino Õunap, Endla Asi. The Estonian Environment Agency, Tartu 2020

Outlook

The forest monitoring activity in Estonia will continue for both levels (Level I and Level II). The forest monitoring group is planning to start the 3rd ICP Forests Level I soil survey in 2020.

Finland

National Focal Centre

Päivi Merilä, Natural Resources Institute Finland (Luke)

Main activities/developments

In 2019, eight Level II plots were monitored for atmospheric deposition, soil solution chemistry, meteorology, and understorey vegetation. As two of the plots are in sapling stands, monitoring activities on the six plots representing mature forests included also litterfall, crown condition and foliar chemistry. In addition, tree increment was monitored using girth bands by manual recordings. The monitoring data of the year 2017 was submitted to the ICP Forests database.

Major results/highlights

Two refereed papers published in 2019 utilized Finnish Level II data and the network. The study of Salemaa et al. (2019)[1] focused on biological nitrogen fixation associated with mosses and lichens sampled from 12 Finnish Level II plots. All terricolous moss and lichen species studied showed nitrogen fixation activity in the northernmost plots, with the highest rates in the feather mosses *Hylocomium splendens and Pleurozium schreberi*. In moss samples taken along the north-south gradient with an increasing N bulk deposition from 0.8 to 4.4 kg $ha^{-1}year^{-1}$, nitrogen fixation clearly declined in both feather mosses and in the *Dicranum* group and turned off at a N deposition of 3–4 kg ha^{-1} $year^{-1}$. Inorganic N deposition best predicted the nitrogen fixation rate. However, in southern spruce stands, tree canopies modified the N in throughfall so

[1] Salemaa M, Lindroos A-J, Merilä P, Mäkipää R, Smolander A. (2019) N2 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

that dissolved organic N (DON) leached from canopies compensated for inorganic N retained therein, and both DON and inorganic N negatively affected nitrogen fixation on *H. splendens*. In conclusion, the results suggest that even relatively low N deposition suppresses biological nitrogen activity on mosses. In future, the nitrogen fixing activity on mosses could increase in northern low-deposition areas, especially if climate warming leads to moister conditions, as predicted.

The study of Ťupek et al. (2019)[1] tested process-based models (Yasso07, Yasso15 and CENTURY) with soil heterotrophic respiration (Rh) and soil organic carbon (SOC) stocks measured at four Level II plots in 2015 and 2016. The models were able to accurately reproduce most of the seasonal Rh trends and amounts of SOC. However, under autumn temperature and moisture, Rh was mismatched before and even after the parameterization. The authors conclude that the seasonality of the temperature and water functions should be adjusted in these models.

Outlook

Monitoring activities will continue on eight Level II plots in Finland, and the data is utilized in several studies both nationally and internationally and for the information needs of the NEC Directive. A solid commitment for funding of the Level II monitoring remains a challenge. In addition to the UNECE ICP Forests programme, two EU related initiatives, the NEC Directive and the acceptance of the eLTER research infrastructure onto the EU's ESFRI roadmap, have strengthened the prospects of the Level II programme in Finland to some extent.

France

National Focal Centre

Level I: Frédéric Delport, Ministère de l'Agriculture et de l'Alimentation

Level II: Manuel Nicolas, Office National des Forêts

Main activities/developments

Monitoring activities were continued on the 102 plots of the Level II network (RENECOFOR). In detail, tree assessments (phenology, health, annual growth, and periodical growth inventory) 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 addition, a national intercalibration course for ground vegetation assessment was organized in July 2019 with all teams of botanists to be involved in the campaign planned on all Level II plots in 2020. This campaign could not start as planned in spring 2020, because most of the botanists were not allowed to go to the field due to the exceptional rules taken by public authorities to slow down the epidemic of COVID-19. But it will hopefully be conducted in 2021.

Outlook

The French Level II network (RENECOFOR) will reach in 2022 its initially defined 30-yr horizon. 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. Then successive workshops were organized with its scientific board to elaborate future scenarios, which had to be scientifically sound, policy-relevant, but also feasible on the long run. A proposal was finalized in November 2019, before the beginning of negotiations between national funders (which are still going on).

The proposal is made of a base scenario with six possible options in addition. The base scenario aims at continuing with the same objectives (to evaluate the impacts of environmental changes on forest ecosystems) with the minimum additional effort to adapt the network to longer-term activity, that is by progressively replacing the plots that have entered or will enter the stand regeneration stage within the next 30 years (about half of the network) by new plots in adult stands. Each of the additional options is a suggestion to complement the field measurements in response to some of the main current concerns:

- to add plots in the French Mediterranean region (not covered so far by Level II), where forest is subjected to the driest conditions and probably the most sensitive to climate change impacts,
- to better satisfy the EU NEC Directive, by repeating every year the ozone assessments and adding one very intensive plot in the Mediterranean biogeographical region,
- to evaluate the impact of the regeneration stage, by maintaining under monitoring some plots that have entered this stage in comparison to new plots installed in an adult stand nearby,
- to install soil moisture sensors to better evaluate drought effects and nutrient fluxes in the subset of 14 plots already monitored for meteorology, deposition, and soil solution chemistry,
- to re-extend litterfall surveys to 50 plots, to better evaluate the C sequestration in forest soils and the responses of trees to stresses (fruit and foliage production, internal nutrient recycling),

[1] Ťupek, B., Launiainen, S., Peltoniemi, M., Sievänen, R., Perttunen, J., Kulmala, L., Penttilä, T., Lindroos, A.-J., Hashimoto, S., Lehtonen, A. 2019. Evaluating CENTURY and Yasso soil carbon models for CO2 emissions and organic carbon stocks of boreal forest soil with Bayesian multi-model inference. European Journal of Soil Science 70:847-858. doi: 10.1111/ejss.12805

- and to add metagenomic analyses of soil biodiversity to the next soil sampling campaigns.

Now it is up to national funders to decide about the future of the RENECOFOR network, depending on their interest for the proposed scenario and possible options, and on the means they can provide.

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 2019 crown condition survey took place on 421 Level I plots with a total number of 10 128 sample trees. Level II data have been submitted for 68 plots.

Major results/highlights

Crown condition Level I

In summer 2019, defoliation on 36% of the forest area was classified as moderate to severe (defoliation classes 2 to 4; this means defoliation >25%). This is an increase by 7 percentage points compared to 2018. 42% of the investigated forest area was in the warning stage (slightly defoliated). Only 22% (2018: 28%) showed no defoliation. Mean crown defoliation increased from 22.0% in 2018 to 25.1% in 2019. This is the highest mean crown defoliation ever recorded since the beginning of the surveys in 1984.

Picea abies: The percentage of defoliation classes 2 to 4 increased from 30% to 36%. 36% (2018: 40%) of the trees were in the warning stage. The share of trees without defoliation was 28% (2018: 30%). Mean crown defoliation increased from 21.5% to 23.9%.

Pinus sylvestris: The share of defoliation classes 2 to 4 increased by 11 percentage points and reached 26% in 2019. The share of the warning stage was 56% (2018: 54%). Only 18% showed no defoliation. Mean crown defoliation increased from 18.3% to 22.4%.

Fagus sylvatica: The share of trees in the defoliation classes 2 to 4 reached 47% (2018: 39%). 37% (2018: 42%) were in the warning stage. The share showing no defoliation was 16% (2018: 19%). Mean crown defoliation increased from 25.1% to 28.6%.

Quercus petraea and *Q. robur*: The share of moderately to severely defoliated trees increased from 42% to 50%. The share of trees in the warning stage decreased from 38% to 33%. The share without defoliation decreased from 20% to 17%. Mean crown defoliation increased from 25.7% to 28.2%.

The vegetation period 2019 as well as the previous summer 2018 were characterized by severe drought and temperatures above the long-term average. An *Ips typographus* gradation is currently ongoing. Extraordinary fellings due to wind, drought and bark-beetle damage, which occurred in 2018 and 2019, and expected fellings in 2020 sum up to a total amount of 160 million cubic meters of timber. An area of 245,000 ha needs to be reforested.

All species groups displayed notable responses to the extreme years 2018 and 2019, yet it is important to note a certain distinction between the responses of beech and those of the other species groups. For coniferous species as well as oaks the proportion of trees with no defoliation has followed a cyclical pattern since 1984. Indeed, years with outcomes comparable to 2019 were observed for oaks in 1996/1997 and 2007/2008, for spruce in 1993 and 2004, and for pine in 1991 and 2008 (although here the distinctly low proportion of healthy trees in 2019 is unprecendeted). In contrast, the proportion of healthy beech trees displays a very different pattern over time: a steady decrease until 2004 is followed by a year-by-year fluctuation driven by mast years. Exceptionally, in 2019 the proportion of healthy beech trees decreased in the absence of a clear mast year. This suggests unprecendented stress levels for beech in the aftermath of 2018 and 2019, and distinguishes it from the other species groups.

The International Cross-Comparison Course 2019 took place 3–6 June 2019 in Chorin, Germany. The course was organized by the Thünen Institute of Forest Ecosystems in cooperation with the Landeskompetenzzentrum Forst Eberswalde and it was attended by 26 participants. Ten National Reference Teams assessed defoliation, fructification and damages on six tree species: *Fagus sylvatica, Quercus petraea and Q. robur*, *Picea abies*, *Pinus sylvestris* and *Betula pendula*. Defoliation assessments displayed moderate to high consistency while fruiting displayed relatively low agreement levels. The assessment of damage causes resulted in comparably low agreement levels and indicated potential for further harmonization (see http://icp-forests.net/group/crowncondition/page/document-archive).

The national training course for the forest condition survey in Germany took place 26–28 June 2019 in Arnsberg. The course was attended by 29 participants and targeted the main tree species in Germany. The results indicated a high reliability of defoliation assessments within Germany.

Intensive forest monitoring (Level II)

Interrelations between climate effects, nutrition, and tree growth were analysed on Level II plots as part of the Dendroklima project financed by the German Waldklimafonds. Dendroecological studies in temperate oaks and Scots pine

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revealed that sensitivity of trees to climate extremes depends on the trees' nutrional status and on soil conditions. For instance, foliar nitrogen and potassium concentrations are linked to the probability that tree growth responding positively to summer precipitation. The results indicate the importance of taking tree nutrition into consideration when analysing the influence of water availability on trees.

In October 2019, a national autumn phenology field calibration course with 18 participants was organized in the Schorfheide. Possibilities to further harmonize methodologies used in different German Federal States were evaluated. Alongside the course, possibilities to enhance ground based assessment of phenology by unmanned aerial vehicles (UVA) were tested. Phenological assessment by UAV allows a better distinguishment of autumn colouring from colour changes due to drought, as well as reproductible quantification of phenological stages.

Tests of a novel sampling system for mercury deposition on the Level II plot Göttinger Wald, a beech stand, showed that non-heated samplers allow reliable measurements, while also being cost efficient and easy to handle and assemble. Additionally, the mercury content of different materials such as fruits and bird droppings were measured to assess the effects of contaminations. As the next step of the project financed by the German Environmental Agency (UBA), testing will be expanded to plots with different tree species such as Norway spruce as well as on chosen Level II plots in Bavaria and North Rhine-Westphalia.

Data from German Level II plots was reported as part of the new EU National Emission Ceilings Directive to monitor impacts of air pollution on forests for the first time in 2019.

Decision support system based on forest monitoring data

In Rhineland Palatinate, a decision support system was developed to identify the sensitivity of forests sites to impairment of the nutrient sustainability. The assessment takes the input-output-budgets and plant available stocks of macronutrients into account. Forest monitoring data was essential for calculating site-specific nutrient fluxes and stocks. The final output consists in statewide maps of the forest area showing the vulnerability class for each management unit and providing recommendations for a sustainable nutrient management.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Wellbrock N, Bolte A [editors] (2019) Status and Dynamics of Forests in Germany. Results of the national forest monitoring. Ecological Studies 237. ISBN 978-3-030-15734-0

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

- Our national working group on environmental monitoring of forests will further consider how to deal with changes on the Level II plots in a harmonized and coordinated way.
- The next national training course for the forest condition survey in Germany will take place 22–25 June 2020 in Freising, Bavaria.
- A new database front-end designed for the input of forest condition data in Germany is currently in the validation-verification phase. It was tested during the 2019 summer campaign by four Federal states and further adjustments will aim to increase its acceptance and usability among operators.
- The reliability of the crown condition survey based on the Photo International Cross-Comparison Course 2019 (Photo ICC) is the subject of ongoing analysis.
- Following the restructuring of the crown condition data in the database, corrected and completed data from from Level II plots has been resubmitted by the Federal States and will be quality checked and analyzed. Results from 30 years of intensive monitoring on German Level II plots will be published in an upcoming report.

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

Crown condition assessment

For the assessment of the crown condition in 2019, data was collected from 46 plots representing a 46% percentage of the total number of the Level I plots in our country. More specifically, in 2019 the number of trees counted was 1055, whereas in 2018 the number of trees was 936. From the 1055 trees, 414 were conifers and 641 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	58.9	41.3	70.2
Slight defoliation	20.5	30.0	14.4
Moderate defoliation	17.0	25.1	11.7
Severe defoliation	2.5	2.9	2.5
Dead trees	1.3	0.7	1.3

It was found that 79.3% of all trees belonged to the classes “No defoliation” and “Slight defoliation”. The corresponding values were 71.3% and 84.6% 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

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

In terms of rainfall in all plots, the average annual height for 2018 was 36% higher than the average annual value (observed for at least 23 years) for all plots. Particularly in the fir plot we observed the highest rainfall in the last 47 years.

Also in all plots, the average annual air temperature was higher than the plot station's average value. More specifically, the increase was 6.9% in the maquis plot (47 years), 9.5% in the oak and beech plots (23 years) and 6.1% in the fir plot (47 years).

Crown condition assessment (Level II)

The crown assessment for the year 2018 in the four Level II plots comprised a total number of 167 trees (35 conifers and 132 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
	2018	40.0	34.3	22.9	2.7	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
	2018	51.5	33.3	9.8	1.5	3.8

Deposition

The following table shows the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak and fir plots in 2018. It can be seen that there was retention of ammonium-N by the canopy of all plots (throughfall < bulk fluxes), whereas the nitrate-N retention took place only in the fir plot. We can conclude that the nitrogen dry deposition was in the form of nitrates. As was expected, the fluxes of magnesium and potassium were higher in the throughfall deposition for all plots. With the calcium and sulphate-S fluxes the results vary. The height of both throughfall and bulk deposition had higher values in the fir plot but the oak plot had high elemental fluxes in the throughfall deposition, another indication that dry deposition may have played an important role.

Fluxes (kg ha^{-1} yr^{-1}) of major ions in deposition (throughfall (T) and bulk (B)) in three forest plots in 2018

Plots	Dep.	Ca	Mg	K	$SO4^{2-}$-S	NH_4^+-N	NO_3^--N	mm
Maquis	T	21.9	4.44	30.2	13.5	0.48	1.28	896
	B	21.8	2.54	5.4	10.0	0.76	1.10	1280
Oak	T	20.6	12.7	39.0	16.0	2.52	6.57	1310
	B	14.2	2.49	13.7	16.6	4.96	3.26	1681
Fir	T	25.6	4.83	30.5	17.8	2.05	1.66	1696
	B	31.4	2.56	7.5	14.8	2.13	2.92	2186

Litterfall

The fluxes of base cations and sulfur in the foliar litterfall are similar in all plots (s. table below). Differences were found in nitrogen and phosphorus, especially for the latter. The oak plot had low phosphorus fluxes in both foliar and non-foliar litterfall. This is something to take into account in case a problem appears.

For the non-foliar litter the fir plot had by far the highest amounts of all nutrients. For all plots and for most nutrients in the below table the non-foliar litter contributed more than half the amount of the nutrients in the foliar litter. This is important when considering the removal of nutrient stocks through logging. The logging remains should stay on the forest floor to enrich the soil. This stands especially for the wooden remains in acid forest soils. The oak and beech plots are situated on a mica schist parent material, which gives rise to acid soils. From the below table it can be seen that for the non-foliar litter (mainly twigs) the quantities of calcium are appreciable. If they are removed, a valuable buffer shield against a soil pH change will deteriorate.

Fluxes (kg ha^{-1} yr^{-1}) of major nutrients in litterfall in four forest plots in 2018

Foliar	Ca	Mg	K	S	N	P
Maquis	48.8	5.78	9.85	3.31	42.0	1.65
Oak	50.6	7.08	13.0	2.83	33.0	0.56
Beech	52.5	4.79	6.89	3.87	41.3	1.42
Fir	58.2	3.93	8.80	3.54	34.0	2.72
Non Foliar	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	13.8	0.84	1.42	0.58	5.3	0.44
Oak	32.3	2.78	5.41	1.34	15.5	0.70
Beech	16.9	1.20	1.11	0.90	9. 9	0.81
Fir	30.5	2.91	7.40	2.60	27.7	1.64

In 2019, a paper was published (reference below) dealing with the distribution, quantification and fluxes of Pb in the maquis ICP Forests plot.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Michopoulos P, Bourletsikas A, Kaoukis K, Kostakis M, Thomaidis NS, Pasias IN, Kaberi H, Iliakis S (2019) Distribution and quantification of Pb in an evergreen broadleaved forest in three hydrological years. Journal of Forestry Research. https://doi.org/10.1007/s11676-019-01018-4

Hungary

National Focal Centre

Pál Kovácsevics, Dóra Nagy
National Land Centre, Department of Forestry

Main activities/developments

Level I, the large scale health condition monitoring, is coordinated and carried out by the experts of the National Land Centre – Department of Forestry. The annual survey includes 78 permanent sample plots with 1872 potential sample trees totally on a 16 x 16 km grid.

In 2019, 78 permanent plots with 1869 sample trees were included in the crown condition assessment. The survey was carried out between 15 July and 15 August. The percenatage of broadleaves was 90.6% while the percenatege of conifers was 9.4%.

Major results/highlights

Level I

From the total number of sample trees surveyed, 31.6% were without visible defoliation which shows a little increase in comparison with 2018 (26.5%). The percentage of slightly defoliated trees was 33.3%, and the percentage of all trees within ICP Forests defoliation classes 2-4 (moderately damaged, severally damaged and dead) was 35.1%. The rate of dead trees was 1.7% and only 0.3% of them died in the surveyed year. The dead trees remain in the sample as long as they are standing but the newly died trees can be separated. The mean defoliation for all species was 26.5%.

Relatively big differences can be observed between the tree species groups in respect of the defoliation rates. In 2019, *Quercus robur* (pedunculate oak) was the most defoliated tree species: the percentage of the sample trees in the healthy category (ICP Forests defoliation class 0) was under 10%. *Pinus nigra* (black pine) has been the most defoliated and damaged tree species in recent years but in 2019 there was some positive alteration in respect of the health condition. *Carpinus betulus* (common hornbeam) and *other hardwood species* were the least defoliated tree species in 2019.

Discoloration can rarely be observed in the Hungarian forests, 89.4% of living sample trees did not show any discoloration.

In 2019 on 75% of all the trees (on all plots) at least one symptom of damage was found. Fungi (24.5%) and insects (23.2%) were the most frequent damaging agents generally but the rates of the damaging agents showed differences in proportions between the tree species respectively. Fungal damages were observed on *Pinus nigra* at the highest rate (65.4%) but the highest damage intensity occurred on *Quercus robur* and on *other oaks,* which correlates with the bad condition of the latter species. The damages caused by insects (mostly defoliators) occurred on *Quercus petraea* (sessile oak) and *Pinus sylvestris* (Scots pine) at the highest rates.

Abiotic damages (16.2%) were the third most frequent damaging agents: most of the observed damages were due to the periods of drought and long-term heatwaves during summer, or frost or wind. The frequency of the damages with unknown origin was 16.1%. The rates of the damages caused by other biotic agents (9.2%) and direct actions of man (5.8%) did not change significantly compared to the previous years. The game damages were generally of low frequency (4.1%) but in some tree species groups (poplars, beech, *Robinia* and hornbeam) appeared more often.

The signs of fire damage were not really observed in the assessed stands (0.9%).

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

"Erdeink egészségi állapota 2019-ban" The annual national report on the health condition of the Hungarian forests, which includes ICP Forests plot data, is available (in Hungarian) online at
http://www.nfk.gov.hu/EMMRE_kiadvanyok__jelentesek__prognozis_fuzetek_news_536

Ireland

National Focal Centre

Thomas Cummins, Soil Science, School of Agriculture and Food Science, University College Dublin

John Redmond, Forest Service, Department of Agriculture Food and the Marine, Wexford

Main activities/developments

Crown condition assessments were undertaken at Level I forest plots, and data submitted to the ICP Forests database. This work is operated by the Forest Service, Department of Agriculture Food and the Marine.

Major results/highlights

Forest health remains good. With new plot selection, no trends are assessable.

Outlook

Monitoring under National Emissions Ceiling Directive Article 9 is expected to lead to the establishment during 2020 and operation of a National Ecosystem Monitoring Network into 2021–2022. The network is likely to operate about eight instrumented sites, two each in forests (restarting ICP Forests monitoring), semi-natural grasslands, bogs, and heaths, as well as three lakes. A network of periodically-assessed sites in the same ecosystems, and including the ICP Forests Level I forest sites, is expected also to be confirmed. The network will be coordinated by Ireland's Environmental Protection Agency, with initiation and support from the Department of Communications, Climate Action and Environment.

Latvia

National Focal Centre

Level I: Uldis Zvirbulis

Level II: Andis Lazdins, Ainars Lupikis
Latvian State Forest Research Institute Silava

Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2019 in Latvia was carried out on 115 Level I NFI plots. The major results of 2019 are based on data from this dataset.

Major results/highlights

In total, defoliation of 1732 trees was assessed, of which 74% were conifers and 26% broadleaves. Of all tree species, 11.3% were not defoliated, 83.2% were slightly defoliated and 5.5% moderately defoliated to dead. Compared to 2018, the proportion of not defoliated trees has increased by 1.4%, the proportion of slightly defoliated has decreased by 1.0%, but the proportion of moderately defoliated to dead trees has increased by 0.5%. In 2019, the proportion of not defoliated conifers was by 8.3% higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was by 4.7% higher than that of slightly defoliated conifers. The proportion of trees in defoliation classes 2-4 for broadleaves was 3.5% higher than for conifers.

Mean defoliation of *Pinus sylvestris* was 20.0% (19.5% in 2018). The share of moderately damaged to dead trees constituted 4.6% (4.3% in 2018). Mean defoliation of *Picea abies* was 18.7% (17.3% in 2018). The share of moderately damaged to dead trees for spruce increased up to 4.2% (2.9% in 2018). The mean defoliation level of *Betula* spp. was 20.9% (20.8% in 2018). The share of trees in defoliation classes 2-4 was 8.0% (compared to 8.8% in 2018).

Visible damage symptoms were observed to a smaller extent than in the previous year – 17.0% of the assessed trees (17.3% of the assessed trees in 2018). Most frequently recorded damages were still caused by direct action of men (30.0%; 35.2% in 2018), animals (25.5%; 26.2% in 2018), insects (16.9%; 11.1% in 2018), fungi (11.8%; 11.1% in 2018), and abiotic factors (11.8%; 13.1% in 2018), unknown cause – for 3.8% (3.4% in 2018). The distribution of damage causes was similar as in last year. The proportion of insect damages has increased thanks to the increase of damages by the European pine sawfly *Neodiprion sertifer*. The greatest share of trees with visible damage symptoms was recorded for *Picea abies* (26.0%), *Pinus sylvestris (16.1%)* and the smallest for *Betula* spp. (9.8%).

Outlook

Latvia has 115 NFI Level I plots and it is planned to carry out observations in this volume. Currently we have 3 sample plots in the Level II monitoring and it is planned to maintain those sample plots also in future. It is planned to continue measurements on all of the Level II plots.

Lithuania

National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

Main activities/developments

Level I

In 2019, the forest condition survey was carried out on 992 sample plots from which 81 plots were on the transnational Level I grid and 911 plots on the National Forest Inventory grid. In total 5956 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 2019, intensive monitoring activities have been carried out on 9 intensive monitoring plots. On these plots crown condition, ozone injury assessment and foliage analysis were carried out. Additional measurements of air quality (SO_2, NO_2 and NH_3), the chemical analysis of deposition (open field and throughfall), soil solution and sampling of litterfall were performed on 3 Level II plots. The crown condition assessment in 2019 on the nine Level II plots took place on a total number of 504 model trees. In 2019, repeated soil monitoring was performed on Level II plots.

Major results/highlights

Level I

During one year the mean defoliation of all tree species slightly decreased up to 22.0% (21.7% in 2018). 15.9% of all sample trees were not defoliated (class 0), 64.9% were slightly defoliated and 19.2% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers slightly increased up to 22.6% (22.4% in 2018) and slightly increased for broadleaves up to 21.1% (20.6% in 2018).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 37% of all sample trees annually. Mean defoliation of *Pinus sylvestris* slightly increased up to 24.4% (23.8% in 2018), while in 2008-2019 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 18.0% (16.7% in 2018) and the proportion of trees in defoliation classes 2-4 was 7.6% comparing with 4.6% in 2018.

The condition of *Fraxinus excelsior* remained the worst among all observed tree species. This tree species had the highest defoliation since 2000. Mean defoliation decreased to 27.4% (34.0% in 2018). The share of trees in defoliation classes 2-4 increased to 40.7% (38.7% in 2018).

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 2011–2019. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (50%), *Populus tremula* (32%), *Alnus incana* and *Picea abies* (31%), the least for *Alnus glutinosa* and *Betula* sp. (17%).

Level II

In general, the mean defoliation of all tree species has varied inconsiderably from 1997 to 2019 and the growing conditions of Lithuanian forests can be defined as relatively stable.

The average defoliation sequences in the intensive monitoring plots since 1995 reflect the main trends in forest condition change identified in the regional forest monitoring. The average defoliation of trees in Level II plots over the last 5 years has ranged from 16 to 17%.

Air pollution deposition surveys, carried out since 2000, show that sulphur deposition under tree crowns has constantly decreased. The amount of sulphur deposition in an open area has fluctuated between 8 to 3 kg ha^{-1} yr^{-1}. Average nitrate deposition (NO_3–N) both in an open area and under tree crowns has fluctuated from 5 to 7 kg ha^{-1} yr^{-1}. Average ammonium deposition in the forest has been equal to around 4-5 kg ha^{-1} yr^{-1}, while in an open area it reached nearly 4 kg ha^{-1} yr^{-1}.

Chlorine and sodium concentrations in open area precipitation showed that Cl (R^2 = 0.85) and Na (R^2 = 0.77) concentrations decrease reliably depending on the distance from the Baltic Sea.

In 2019, visually visible ground-level ozone-related damages were assessed on all 9 intensive monitoring plots. Despite the fact that the air temperature of this year's vegetation season was relatively high, no foliage damage similar to that caused by ground O_3 was recorded. During the 2007–2018 observation period, ground-level ozone damaged an average of 0.16% of all assessed vegetation.

Outlook

The implementation of soil monitoring is planned in 81 Level I monitoring plots in 2020.

Montenegro

National Focal Centre

Ranko Kankaraš, Ministry of Agriculture and Rural Development

Main activities/developments

The national focal point is in the Ministry of Agriculture and Rural Development.

Field data are collected by the teams of the Forest Directorate (10 teams are established for field work), according to the set locations outside at the 16 x 16 km network. In front of the Forest Directorate, the field of forest protection, which is headed by Zehra Demic, is in charge of organizing and logistics of field activities in ICP Forests data collection.

The control of fieldwork, entry of data and processing of the data are performed by the Institute of Forestry of Montenegro. Aleksandar Stijović is in charge of the Forestry Institute of Montenegro, while the executive director is Slavisa Lučić.

Major results/highlights

The monitoring of forest health in Montenegro is established at 49 bioindication points in a 16 x 16 km network.

24 trees were processed on each of the 49 monitored areas (1176 trees in total) on which the crown condition was assessed, the occurrence of damage, the degree of defoliation of assimilation organs, pathogenic and parasitic micro-organism symptoms, symptoms of abiotic and climatic effects, insect and game damage, human activity, forest fires and other parameters that determine the degree of damage to the species observed.

Of the observed 1176 trees, 888 were broadleaves and 288 were conifers.

Looking at the separate broadleaves, beech makes up a third of the total number of hardwoods 33.7%, while oaks (various species) make up 26.2%, black ash 10.9% and ordinary hornbeam 9.5%, while other types of broadleaves have a smaller share.

Looking at the conifers separately, at the bioindication points the proportion of fir and spruce was similar (firs 34.7% and spruce 35.4%). These two species make up more than 70% of conifers at the observation points. In addition to fir and spruce, the share of black pine is significant, 24.3%, while the share of other conifers is 5.6%.

By defoliation rate 18.3% is defoliation free, slightly defoliated are 48.0%, moderately defoliated are 29.1%, severely defoliated are 4.6% and there were no dead trees.

The participation of tree individuals in relation to the causes of damage is as follows: 18.4% of the observed trees are free of damage, insect damage is on 31.2% of the observed trees, pathogenic fungal damage is present on 15.0% of the observed trees, abiotic effect is present on 22.5% of the observed trees, and human impact is present on 3.6% of the observed trees. Consequences of forest fires are visible on 4.3%, while pollutants as the causing agent are registered on 0.6% and the rest of 4.5% are established but not identified causes on observed trees.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Montenegro Forest Health Monitoring Report (ICPF - International Forest Cooperative Monitoring Program for Europe) for 2019, Institute of Forestry of Montenegro and Ministry of Agriculture and Rural Development of Montnegro, Podgorica, February 2020

Outlook

Planned research projects with remediation plan for forest in Mountain Ljubišnja in 2020. The project is planned on the causes of the drying of forests on the mountain Ljubišnja in the Municipality of Pljevlja (analysis of the causes of the drying and preparation of a remediation plan). Research on the causes of the drought and the preparation of the remediation plan should be carried out by the Forestry Institute of Montenegro, and published by the Ministry of Agriculture and Rural Develoment by the end of 2020.

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

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 2019 we participated in the ICP Forests Joint Expert Panel Meeting in Brussels (March), the Scientific Conference and Task Force Meeting in Ankara (June), the International Photo-Intercalibration Course and the PCG meeting in Berlin (November). We also took part in a working group under the Norwegian Environment Agency evaluating the Norwegian monitoring network on effects of air pollution in light of the NEC-Directive (which still has not been implemented in Norway).

Level I/Norwegian national forest monitoring

The Norwegian national forest monitoring is conducted on sample plots in a systematic grid of 3 x 3 km in forested areas of the country. The plots are part of the National Forest Inventory (NFI), who also is responsible for crown condition assessments including damage. The NFI has five-year rotation periods, and since 2013 monitoring has also been carried out with five-year intervals on the same plots, and not annually anymore. Sample trees are selected with a relascope. Defoliation assessments are done on Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) only, while damage assessments are conducted on all tree species.

In 2019, national defoliation assessments were carried out on 5 811 Norway spruce and 4 721 Scots pine trees on 1 863 plots, damage assessments on 19 235 trees (25+ species) on 2 568 plots from mid of May until mid of October. A national field calibration course with 25 participants from the NFI was arranged for the monitoring in May 2019. All field workers from the NFI also participated in ICP Forests International Photo-Intercalibration Course during the field season 2019.

In 2019, 687 plots were part of the transnational ICP Forests Level I grid (16x16 km = 1 plot pr. 256 km^2), and defoliation and/or damage data for 5 651 trees belonging to 24 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). Long-term ozone and meteorology data have been submitted to the ICP Forests Collaborative Database. 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 2019. We participated in several international, collaborative projects with data and samples from our Level II plots: the role of pollen in forest C and N cycling (INBO, ICP Forests project 123), Hg measurement campaign in European forests (University of Basel) and Microbiome-enabled forecasting of forest composition and function in European forests (ETH Zürich/University of Tartu, ICP Forests projects 168/115).

Major results/highlights

Norwegian national forest monitoring

In 2019, mean defoliation for Norway spruce was 16.5%, and 14.0% for Scots pine in our national monitoring. Defoliation increased slightly for both Norway spruce and Scots pine compared to 2018.

When dividing into defoliation classes, 46.8% of the spruce trees and 45.8% of the pine trees were classified as not defoliated (Defoliation class 0) in 2019, which represents a decrease of 3.5 and 1.8%-points, respectively. Class 1 (slight defoliation) comprised 33.2% of the spruce trees and 42.6% of the pine trees, while 16.6% and 10.6% of the spruce and pine trees fell into class 2 (moderate defoliation). Severe defoliation (class 3) was recorded for 3.4% of the spruce trees and for only 1% of the pine trees.

Less damage was observed in 2019 than in 2018 and only 12.5% of all assessed trees had some symptom of damage (-2.7%-points compared to 2018). 10.5% of the spruce trees were damaged (-1.3%-points), 7.9% of the pines (-1.4%-points) and 15.9% of the birches (*Betula* spp., -6.5%-points). For other deciduous species damage increased to 19.2% (+3.9%-points). Of special concern is the high percentage of damaged oak trees (*Quercus* spp.), 29.1%, which was more than 3 times higher than in 2018. The prevailing causes of damage for all tree species were abiotic factors with snow breakage, storm and drought as the most important ones. Insects were the second most important causes of damage for pine and birch – but not for spruce with only a few recorded incidents of insect damage. The percentage of unidentified damage causes was considerably higher than in 2018 (44.8% for all species, +13.2%-points), and was especially high for spruce (61.8%-points). Little discolouration was observed in the conifers in 2019, only 5.3% of the spruce trees and 1.3% of the pine trees had discolouration of more than 10%.

Mortality rates were 3.5‰ for Norway spruce, 2.1‰ for Scots pine, 7.6‰ for birch, 10.6‰ for other deciduous species and 5.3‰ on average for all assessed tree species in 2019.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Garmo Ø. (NIVA), Vegar Bakkestuen (NINA), Sverre Solberg (NILU), Volkmar Timmermann (NIBIO), David Simpson (Met), Ane Victoria Vollsnes (UiO), Per Arild Aarrestad (NINA) og Sissel Brit Ranneklev (NIVA) 2020. Forslag til norsk overvåkingsnettverk for å oppfylle NEC-direktivets krav om å overvåke effekter av luftforurensing. [Recommendation for the Norwegian monitoring network to meet the criteria of the NEC-Directive on monitoring effects of air pollution.] NIVA rapport 7456-2020. 51 pp + annexes. ISBN 978-82-577-7191-1. ISSN 1894-7948

Timmermann V, Andreassen K., Brurberg MB., Børja I, Clarke N., Flø D, Jepsen JU., Kvamme T, Nordbakken JF, Nygaard PH, Pettersson M, Solberg S, Solheim H, Talgø V, Vindstad OPL, Wollebæk G., Økland B., Aas W (2019) Skogens helsetilstand i Norge. Resultater fra skogskadeover-våkingen i 2018. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2018.] NIBIO Rapport 5(98). 81pp. ISBN 978-82-17-02387-6. ISSN 2464-1162. https://nibio.brage.unit.no/nibio-xmlui/handle/11250/2616613

Outlook

- Monitoring at Level I will continue as part of our national monitoring conducted by the NFI.
- The planned installation of an ICOS C-flux tower at one of our Level II sites (Hurdal) was heavily delayed, but will hopefully be completed during 2020. 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 2019, the forest condition survey was carried out on 2 042 Level I plots (8 km x 8 km grid) and a total number of 40 840 trees was assessed. Out of that, results of the assessment made on 346 plots on a 16 km x 16 km grid (European network) from about 6 920 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 all plots periodic dendrometric measurements of stands and ground vegetation assessments were made as well as 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 performed.

Major results/highlights

Level I

Forest condition (all tree species total) revealed a slight deterioration as compared to the previous year. 8.3% of all sample trees were without any symptoms of defoliation, indicating a decrease by 3.0 percent points. The proportion of defoliated trees (classes 2-4) increased by 2.6 percent points to an actual level of 21.2% of all trees. The average total defoliation of all species amounted to 23.4%, that of coniferous trees in total to 23.3% and of deciduous trees in total to 23.7%.

Deciduous species were characterized by a higher share of healthy trees (11.6%) and a higher share of damaged trees (23.9%) than coniferous species (respectively: 6.3% and 19.6%). The share of trees from the early warning class (slightly damaged trees, with defoliation of between 11% and 25%) amounted to: for all species – 70.5%, for coniferous species – 74.1%, and for deciduous species – 64.5%.

With regard to the three main coniferous species, *Abies alba* remained the species with the lowest defoliation (12.7% trees in class 0, 12.6% trees in classes 2-4, mean defoliation amounting to 19.8%). *Pinus sylvestris* was characterized by a lower share of trees in class 0 (5.4%), a higher share of trees in classes 2-4 (19.4%) and a higher mean defoliation (23.3%) than *Abies alba*. *Picea abies* was characterized by the highest share of trees in classes 2-4 (25.0%) and the highest mean defoliation (25.0%) compared to Scots pine and fir. The percentage of healthy Norway spruce trees (with defoliation of up to 10%) amounted to 11.9%. *Pinus sylvestris* indicated a slight worsening compared to the previous year.

In 2019 as in the previous survey, the highest defoliation amongst broadleaved trees was observed in *Quercus* spp., although a worsening was indicated compared to the previous year. A share of 2.9% of oaks was without any symptoms of defoliation and 46.3% was in defoliation classes 2-4, the mean defoliation amounted to 30.1% (respectively: 4.4%, 36.3% and 26.0% in 2018). A better condition was observed for *Betula* spp. (8.1% trees without defoliation, 22.6% damaged trees (classes 2-4) and the mean defoliation amounted to 24.1%) than for *Quercus* spp. *Fagus sylvatica* remained the broadleaved species with the lowest defoliation, although a worsening was indicated compared to previous the year as well. In 2019 a share of 18.7% of beech trees was without any symptoms of defoliation, only 10.4% were in defoliation classes 2-4, the mean defoliation amounted to 18.5% (respectively: 28.2%, 6.9% and 16.9% in 2018). *Alnus* spp. was a little more defoliated (18.3% trees without defoliation, 10.7% trees in classes 2-4, the mean defoliation amounted to 19.2%) than *Fagus sylvatica*.

Level II

Meteorological measurements on Level II plots revealed that 2019 was quite hot, with an average annual temperature higher than in 2018 at 10 out of 12 locations, with the highest daily temperature of 39.2 °C in the Krucz Forest District (Western Poland). The precipitation was slightly higher than in 2018.

Results of deposition and the concentration of elements in soil solution on 12 Level II plots will be evaluated in the second half of 2020. The concentration of SO_2 in the ambient air in 2019 was on most plots lower by 1% to 35% than in 2018, and higher by 9% to 20% than in 2018 on 3 out of 12 plots, two of them situated in the least polluted regions of the country. The concentration of NO_2 on most plots dropped by 2% to 24% and only on one plot rose by 5% compared to 2018. A generally decreasing tendency of gaseous pollutants on most of the plots in recent years continued.

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 the 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, Stefan Leca
National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea"

Main activities/developments

In 2019, Romania organized the 7th Meeting of the Heads of the Laboratories in Brasov from September 5–6, 2019. The meeting was organized by INCDS „Marin Drăcea" and 30 participants from 16 countries were present at this event. The results of the last ring tests (water, foliage and soil) were presented. Limits for heavy metals (Cd, Co, Cr, Cu, Ni, Pb and Zn) in water samples were fixed and a water ringtest will be performed annually. The future of aqua regia digestion from soil samples with microwave, mercury deposition samplers and determination of mercury in these samples were presented and discussed. Three presentations about phosphorus and phosphorus fractions in soil were given. The final version of the ICP Forests Manual update was presented and the verification of the submitted data from the LQA file was started.

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

- The 25th IUFRO World Congress, Curitiba, Brazil, September 29, 2019 to October 5, 2019
- Ovidiu Badea, Ionel Popa, Diana Pitar, Stefan Leca, Ecaterina Apostol, Albert Ciceu, Serban Chivulescu. *Climate change and air pollution effects on forest ecosystems status in representative Romanian Level II monitoring plots*
- Ovidiu Badea, Ionel Popa, Stefan Leca, Diana Pitar, Ecaterina Apostol, Serban Chivulescu. *Existing long-term monitoring networks in Romanian forests*
- The 35th Task Force Meeting of ICP Forests and the 8th ICP Forests Scientific Conference, Ankara, Turkey, 11–14 June 2019
- Albert Ciceu, Stefan Leca, Cristian Sidor, Ionel Popa, Serban Chivulescu, Diana Pitar, Ovidiu Badea. *Species adaptability to drought quantified by crown condition resilience components in the Romanian Level I monitoring network*
- Ionuț-Silviu Pascu, Alexandru-Claudiu Dobre, Stefan Leca, Ovidiu Badea. *Improvement of current phenological analysis techniques through the use of multitemporal TLS observations.*
- National Scientific Conference: *State of the Romanian forests – present and future.* Romanian Academy, May 23, 2019
- Stefan Leca, Gheorghe Marin. *Present state of the Romanian forests.*
- The International Cross-Comparison Course Crown Condition (Central and Northern Europe), Chorin, Germany, 3–6 June 2019
- The Joint EP Meeting on Crown Condition, Soil & Soil Solution, Foliage and Litterfall, Deposition and QA/QC in Labs, Brussels, 25–29 March 2019
- MOnitoring ozone injury for seTTing new critical LEvelS – MOTTLES, 3rd Progress Meeting. Câmpulung Moldovenesc - Romania, 1 - 4 July 2019

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

- Annual crown condition assessments on Level I plots (16x16 km).
- Forest monitoring activities on Level II plots: crown condition and tree growth 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); litterfall and LAI measurements (3 plots); ground vegetation assessments (12 plots); 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 data base for all monitoring activities (Level I and Level II).

Major results/highlights

During 15 July and 15 September 2019, the forest condition survey in Romania was conducted on 240 plots from the 16 x 16 km transnational Level I grid network.

From a total number of 5760 trees, 989 trees were conifers (17.3%) and 4771 broadleaves (82.7%), 55.6% were rated as healthy (defoliation class 0), 33.2% as slightly defoliated (class 1), 9.9% as moderately defoliated (class 2), 1% as severely defoliated (class 3) and 0.1% were dead (class 4).

The overall share of damaged trees (defoliation classes 2-4) was 11.6%, with 2.1 percent lower than in 2018. So compared to the previous year, in 2019 the crown condition of Romanian forest recorded a slight improvement.

For conifers, 13.7% of the assessed trees were classified as damaged (defoliation classes 2-4) with 1 percent higher than in 2018. *Picea abies* was the least affected coniferous species with a share of damaged trees of 12.4%, whereas *Abies alba* had 9.9%.

For broadleaves, 11.2% of the trees were recorded as damaged (defoliation classes 2-4) with 2.7 percent lower than in 2018. Among the main broadleaved species, *Fagus sylvatica* and *Robinia pseudoacacia* had the lowest share of damaged trees (6.6% and 7.7%, respectively). The *Quercus spp.* (*Q. petraea, Q. cerris, Q. robur, and Q. frainetto*) registered in 2019 a share of damaged trees of 11.9%, with aprox. 9% lower than the previous year, this being considered as one of the most relevant improvement of oaks health status registered in the last decade. Similar to the previous year, *Fraxinus and Populus* continues to be the most affected broadleaves species (with 34.3% of damaged trees and 19.0%, respectively).

Damage symptoms were reported for 31% of the total number of trees. The most important causes were attributed to defoliators and xylophage insects (27.8%) and fungi (15.8%).

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

- The Annual Report of the Romanian Environment Status in 2018
- The Annual Report of the Romanian Forest Status in 2018
- ICP Forests 2018 Technical Report
- Report of monitoring data in accordance with Article 10 of the NEC Directive.

Outlook

The research/monitoring activity in Level I and Level II plots in Romania is supported by several research projects as the Nucleu Progam - BIOSERV (financed by the Romanian Ministry of Research and Innovation) or the Life15 MOTTLES project.

In the framework of the EO-ROFORMON (http://eo-roformon.ro/) project, we will define the requirements for a national forest monitoring system based on Earth Observation and in situ data. The forest monitoring system will allow the retrieval of an organized time series of measurements for defined biological variables designed to provide defensible answers to questions about forest status and changes. The monitoring system would provide the basis for informed decision making (policies and socio-economic) in forest resource management. A case study analysis for the definition of a national forest monitoring system will be carried out based on the corpus of knowledge developed in EO-ROFORMON and the other Romanian research/monitoring networks like ICP Forests or LTER. The synergy between the information provided by the transnational ICP Forests network and the use of EO data will be considered.

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 2019 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 the public enterprise `Srbijašume`, National Parks, as well as forest owners.

Major results/highlights

During 2019, the researchers of the NFC Serbia - Institute of Forestry with researchers from other institutions in Serbia, visited all sample plots and made a visual assessment of crown condition and collected other necessary field data.

The total number of trees assessed on all sampling points was 2990 trees, of which 356 were conifer trees and a considerably higher number i.e. 2634 were broadleaf trees. The conifer tree species are: *Abies alba,* number of trees and percentage of individual tree species 67 (2.2%), *Picea abies* 143 (4.8%), *Pinus nigra* 67 (2.2%), *Pinus silvestris* 79 (2.6%) and the most represented broadleaf tree species are: *Carpinus betulus,* number of trees and percentage of individual tree species 120 (4.0%), *Fagus moesiaca* 833 (27.9%), *Quercus cerris* 533 (17.8%), *Quercus frainetto* 399 (13.3%), *Quercus petraea* 199 (6.7%) and other species 550 (18.4%).

The results of the available data processing and the assessment of the degree of defoliation of individual conifer and broadleaf species (%) are: *Abies alba* (None 86.6, Slight 8.9, Moderate 3.0, Severe 1.5 and Dead 0.0); *Picea abies* (None 93.7, Slight 2.8, Moderate 2.8, Severe 0.7 and Dead 0.0); *Pinus nigra* (None 40.3, Slight 23.9, Moderate 23.9, Severe 11.9 and Dead 0.0); *Pinus silvestris* (None 78.5, Slight 17.7, Moderate 1.3, Severe 2.5 and Dead 0.0). The degree of defoliation calculated for all conifer trees is as follows: no defoliation 78.9% trees, slight defoliation 11.2% trees, moderate 6.5% trees, severe defoliation 3.4% trees and dead 0.0% trees. Degree of defoliation calculated for all broadleaf species is as follows: no defoliation 78.6% trees, slight defoliation 12.7% trees, moderate 6.7%, severe defoliation 1.8% trees and dead 0.2% trees.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

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 (2019) Forest vitality with a special emphasis on abiotic agents in the Republic of Serbia in 2019. Sustainable Forestry, tom 79-80. Institute for Forestry, Belgrade. ISSN 1821-1046, UDK 630:103–115

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, during 2019 activities in the future development of the infrastructure in this project started by developing special solutions for entering and processing the collected data. During 2020, this will include the use of modern technologies in forest monitoring that 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 damages, 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. During 2020 this software and hardware solution will be developed. This will include the establishment of an appropriate information system through the realization of the following activities:

- introduction of hardware and system software;
- installation of system software and database management software;
- development of the database and applications;
- coding 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;
- 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

Crown condition assessment on Level I plots (16 x 16 km grid) was conducted between 17 July and 16 August 2019 (3 teams in parallel). The number of Level I plots is decreasing due to bark beetle outbreaks and sanitary fellings and relatively large areas with young forest plantations. Activities of intensive monitoring continue on 6 Level II monitoring plots with a frequency of twice per month. One Level II plot was established (moved) after destruction of the original forest stand. 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. After a gap of several years also sampling of needles and leaves was conducted.

We participated in many activities organized by ICP Forests bodies (2019 photo assessment – ICC course, ring tests of laboratories, meeting of Expert panels etc.).

National discussion and the introductory phase started about repetition of soil condition sampling, analyses and assessment. Research activities have continued based on national Level I and Level II data, focussing on nutrient pools and nutrient balance in forest ecosystems, carbon cycling, wood production, effects of climate change on forests. 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 2019 national crown condition survey was carried out on 100 Level I plots of the 16x16km grid. The assessments covered 4423 trees, 3715 of which were being assessed as dominant or co-dominant trees according to Kraft. Of the 3715 assessed trees, 38.8% were damaged (defoliation classes 2-4). The respective figures were 45.3% for conifers and 34.8% for broadleaved trees. Compared to 2018, the share of trees defoliated more than 25% decreased. Mean defoliation for all tree species together was 27.3%, with 29.8% for conifers and 26.0% for broadleaved trees.

After a continuous increase of mean defoliation in the years 2006–2014, no trend is confirmed in the last year but substantial interannual changes were detected in the last years for main broadleaved tree species (beech, oak, hornbeam). The fluctuation of defoliation depends mostly on meteorological conditions. In 2019, the highest mean defoliaton was detected for Scots pine, European larch and ash. Though the defoliation (in total) in 2019 was slightly lower than in 2018, substantial worsening of crown condition was recognized in Scots pine and oaks.

Radial increment of European beech, hornbeam and Scots pine is decreasing (correlated with a defoliation increase) in the last two decades while the increment of Norway spruce and oaks is relatively stable. As already mentioned, specific results are for Norway spruce: defoliation and increment of surviving trees is without an 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 a decline in the 80s in the 20th century.

Deposition of sulphur and nitrogen does not show a further decrease in the last decade. The annual deposition of sulphur (in throughfall) varies between 3 and 9 kg ha^{-1} on monitoring plots, the annual deposition of nitrogen (in throughfall) varies between 5 and 10 kg ha^{-1}. Concentrations of tropospheric ozone are still very high, for a better evaluation of the effect on tree species also models of stomatal uptake are tested.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

A national report on forest condition is not published annually, the main defoliation data are included in the national green report (forestry status).

Selection of articles and other publications:

Tóthová S, Pavlenda P, Sitková Z, Krupová D (2019) Long-term assessment of abiotic factors´ effect on forest ecosystems in Slovakia. In: Kožnárová V (ed.) Proceedings from the conference "Effect of abiotic and biotic stressors on plant features, 3–5 September 2019, Prague, Czech Republic, pp. 168–171 (in Slovak)

Pavlenda, P., Sitková, Z., Pavlendová, H., 2019: Intensification of biomass removal for energy – risks, proposal of evaluation criteria and solution. Outcomes for forestry practice. NFC, Zvolen, 2019, pp. 25-34 (in Slovak)

Outlook

We intend to continue with the monitoring activities at all Level I plots and 7 Level II sites. One of the Level II plots (Polana – Hukavsky grun) with the surrounding research plot 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 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 an NFI subset of plots due to a national project on forest soils that started in 2019.

Slovenia

National Focal Centre

Mitja Skudnik, Daniel Žlindra, Tom Levanič, Primož Simončič, Špela Planinšek – 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, 356 coniferous and 700 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 2019, deposition and soil solution monitoring was performed on all four Level II core plots. On nine (out of ten) plots the ambient air quality monitoring (ozone) was done with passive samplers and ozone injuries were assessed. On eight plots the phenological observations were carried out. On six plots growth was monitored with mechanical dendrometers.

Major results/highlights

- The mean defoliation of all tree species was estimated to be 28.0% (compared to last year the situation worsened).
- The mean defoliation in 2019 for coniferous trees was 28.7% (in 2018 it was 27.7 %).
- The mean defoliation in 2019 for broadleaved trees was 27.6% (in 2018 it was 27.2 %).
- The share of trees with more than 25% defoliation (damaged and dead trees) in 2019 again increased compared to 2016 from 33.8% to 37.7%, but slightly decreased compared to 2017.
- The percentage of damaged broadleaved trees increased from 33.9% in 2018 to 35.1% in 2019.
- The percentage of damaged coniferous trees increased from 40.6% in 2017 to 42.7% in 2019. In past years the coniferous forests are continuously and strongly damaged by insects.
- The defoliation of coniferous trees in 2019 remained on a very high level, with no sign of decrease. The main reason is the bark beetle outbreak after a large ice storm break in 2014, stretching all over 2016, 2017, 2018.
- Average ozone concentrations in the growing season of 2019 were from 28 to 75 µg/m^3 on monitored plots which is slightly higher (around 1 µg/m^3) than in 2018. On 6 out of 9 plots the average 14-days ozone concentration ascended over 80 µg/m^3 during the growing season at least in one period. On the other three plots the highest concentration varied between 48 and 60 µg/m^3.
- The highest average 14-days concentration was 112 µg/m^3 and 75 µg/m^3 on average on the most ozone-polluted plot.
- On three Level II core plots total nitrogen (N) in bulk increased (20–33% to previous year) and decreased by 20% on one plot. Sulphur (S) slightly decreased on all four plots (4–17%).
- Total nitrogen in throughfall decreased (5 and 7%) on two plots and increased on the other two (9 and 55%). Sulphur in throughfall decreased on three plots (6, 18 and 26% respectively) and increased on the fourth (11%).

Outlook

Some minor repair work has been done on IM (Level II) plots in 2019 and will continue in 2020. Some Level I plots were reestablished in the past 4 years, due to major infrastructural projects or clearcuts (after ice storm, bark beetles).

Spain

National Focal Centre

Elena Robla, Area Manager of the Forest Inventory and Statistics Department

Ana Isabel González and Belén Torres, Technicians at the Forest Inventory and Statistics Department

Main activities/developments

Spanish forest damage monitoring comprises:

- European large-scale forest condition monitoring (Level I): 14 880 trees on 620 plots
- European intensive and continuous monitoring of forest ecosystems (Level II): 14 plots

Level I and Level II surveys were carried out successfully in 2019.

Main activities were:

- May 2019: National Intercalibration Course
- March 2019: Attendance to ICP Forests Combined Expert Panel Meeting (Brussels)
- Others: Continuously updating website

Major results/highlights

Level I

Mean defoliation observed in 2019 of all the trees of the Level I sample is 23.9%. Dead trees due to harvests were not included when calculating mean defoliation.

Results obtained from the 2019 surveys show a light regression in general assessed tree status, compared with the mean values from the last 5-year period: The percentage of healthy trees has decreased (73.1%, compared to 78.9% on average in the last 5-year period), and damaged trees have increased (24.3% of the assessed trees have defoliation over 25%, while the average is 18.5%). However, the percentage of dead or missed trees deacreased slightly (2.5% in 2019 compared to 2.7% on average). Comparing broadleaves and conifers, both groups suffer a decline, more clearly in conifers. In this group, the percentage of healthy trees decreased considerably (73.3% in 2019, compared to 80.5% on average in the last 5-year period); and the percentage of damage trees rose up to 23.1% of trees. In the case of broadleaves, the percentage of healthy trees decreased (73.0%, compared to 77.3% on average); the percentage of damaged trees increased as well considerably up to 25.5%.

Finally, as a conclusion, the 2019 overall results show a decline of trees higher than the last 5-year period values. High defoliation values assessed might be related to drought periods every time longer and more extreme, affecting the recovery capacity of stands.

Level II

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

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Level I[1]

- Forest Damage Inventory 2019 (Inventario de Daños Forestales 2019)
- Maintenance and Data Collection. European large-scale forest condition monitoring (Level I) in Spain: 2019 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 2019).

Level II[2]

- European intensive and continuous monitoring of forest ecosystems, Level II. 2018 Report. (*Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II*).

Spanish versions are available for download.

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.

Spanish National Forest Inventory-type plots have been installed with the same centre plot location as Level I plots, in order to fill in the gaps in area estimation and complete the information as regards the living biomass and stand variables. Dasometric parameters as mean diameter, basal area, mean height of living trees are already measured in all Level I plots.

Moreover, regional Level I surveys are being carried out by different regions (autonomous communities) in Spain. An integrated database, containing data both from national and regional sources, has been constructed in the framework of a collaboration between the National Institute for Agricultural and Food Research and Technology (INIA) and the Ministry of Agriculture, Fisheries and Food.

Finally, Spanish Level II plots are part of the "Monitoring air pollution impacts system" established in the framework of the National Emission Ceiling Directive (NECD). A first reporting obligation, containing data from Level II plots, was deliveded on 1 July 2019. Mainly to fulfil the requirements of the NECD Directive, new soil surveys are foreseen in Level II plots.

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 remeasured 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 participated in the joint Expert Panel meeting of ICP Forests and the ICP Vegetation expert workshop assessing and estimating ozone impacts on forest vegetation.

Major results/highlights

The major results concern only forests of thinning age or older and outside forest reserves. The results show an increased number of defoliated *Picea abies* as well as *Pinus sylvestris* trees during the last years. The proportion of trees with more than 25% defoliation is for *Picea abies* 23.2% and for *Pinus sylvestris* 12.3%. Large temporal annual changes are seen on regional level, however during the last five years defoliation is about on the same level for *Picea abies*. For *Pinus sylvestris* a

[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

slight deterioration in northern Sweden is seen during the last 10 years. The mortality rate in 2019 was for *Pinus sylvestris* 0.45% and for *Picea abies* 0.52%. The damage caused by spruce bark beetle (*Ips typographus*) in southern Sweden has continued to increase after the dry summer in 2018. Approx 7 million m^3 Norway spruce forest was killed during 2019. In northern Sweden there is a strong concern for the young forest, mainly the pine forest. Several causes of damage interact. Most important among them are resin top disease (*Cronartium flaccidum*) and browsing by ungulates – mainly elk. But also other fungi are present as pine twisting rust (*Melampsora pinitorqua*) and on Norway spruce there have been recurrent infestations of rust fungi.

Outlook

Monitoring activities on Level I will continue as previously. Also data from SWETHRO on the Level II programme will continue. Several studies are ongoing and among them a study of eutrophication in the moss layer.

Switzerland

National Focal Centre

Arthur Gessler, Peter Waldner, Marcus Schaub, Anne Thimonier, Katrin Meusburger, Swiss Federal Research Institute WSL

Main activities/developments

- The preparation of the 9th ICP Forests Scientific Conference on *Forest Monitoring to Assess Forest Functioning under Air Pollution and Climate Change*, 8-10 Jun 2020, WSL (https://sc2020.thuenen.de/)
- The preparation of the ICP Forests - SwissForestLab - NFZ Summer School on FORMON *Forest Monitoring to Assess Forest Functioning under Air Pollution and Climate Change*, 23-29 Aug 2020, Davos, Switzerland (https://www.wsl.ch/en/about-swissforestlab-summer-school-2020.html)
- Invited speaker at the Workshop on *Regional Impact Assessment on Atmospheric Deposition and Air Pollution on Forest Ecosystems*, Asia Center for Air Pollution Research ACAP, 21 Nov 2019, Niigata, Japan
- Organization of sessions B4g & B4i on *Long-Term Forest Monitoring Networks for Evaluating Responses to Environmental Change*, XXV IUFRO World Congress, 29 Sep-5 Oct 2019, Curitiba, Brazil
- Organization of the 8th UNECE/ICP-Forest Scientific Conference, 10-14 Jun 2019, Ankara, Turkey
- The Swiss Level II plots are on the 2018 *Roadmap for Research Infrastructure of the European Strategy Forum on Research Infrastructures* (ESFRI; http://roadmap2018.esfri.eu)
- The project on *Predicting Ozone Fluxes, Impacts and Critical Levels on European Forests* (PRO3FILE) has been completed. The final report was accepted by the Swiss Federal Office for the Environment and three publications are in process.
- In a follow-up of the FP7 project Eclaire we took lead in analyzing the effects of climate and impacts of site quality, air quality and climate on growth of European forest ecosystems. The publication by Etzold et al. *Nitrogen deposition is the most important environmental driver of growth of pure, even-aged and managed European forests* was published in 2020.
- We have started drone based remote sensing assessments to study canopy level stress parameters (e.g,. photochemical reflectance index, infrared) and compare them with ground-based crown condition assessments
- The technical components of the majority of the meteorological stations on the Level II plots (forest stand and open field) were renewed in 2019. New soil water stations with additional water content sensors (EC-5, Meter group) and new automatic soil water potential sensors (TensioMark) were installed on the majority of plots in 2019. During installation, samples were taken to determine the bulk density.
- In the frame of a SNF funded PhD study, we are going to analyse regularly the stable isotope composition of deposition, soil solution and sap flow water and use this information to improve the water balance modelling and nutrient flux estimations.
- A Swiss wide modelling of the soil water balance on a 500 m grid was carried out with LWFBrook90 and will be compared to early senescence signals derived from e.g. Sentinel satellite data.
- In addition to April to September ozone (O_3) monitoring, ambient air concentrations of nitrogen dioxide (NO_2) and ammonia (NH_3) have been determined with passive samplers on monthly resolution at selected Level II plots for the whole year 2019. Tests for the determination of deposition using resin methods were continued on one plot.
- Intensive work has been carried out to investigate the effects of summer drought, e.g. during 2018, on tree fruit production and stem wood increment. Similarly, effects of drought stress on leaf traits were investigated based on measurements on plots along a water availability gradient in Switzerland.

- Participation in the soil humus sampling on Level II plots in the frame of the project 'Microbiome-enabled forecasting of forest composition and function' (C. Averill, ETH Zürich).

Major results/highlights

In 2019, the defoliation increased again after it had been decreasing from 2017 to 2018. The proportion of "significantly damaged trees[1]" between 30% and 100% increased from 23.5% in 2018 to 33.4% in 2019. The basis for this data is the crown assessment for a total of 1004 trees on 47 plots in 2019. The percentage of highly damaged trees as observed in 2019 is in the upper range of the most recent period (2005 to 2017), where the average of significantly damaged trees amounted to 26.5% of all trees assessed. 2018 has been one of the most intensive drought years in Europe and Switzerland ever detected. In the comparably dry year 2003 the proportion of highly damaged trees was lower (14.9%) than in 2018. Normally we see an increase in defoliation with a time lag of a year after a drought event and in 2004 the proportion increased to 29.2%, still lower than the value in 2019. 2019, however, can also be classified as an extraordinary hot year with lower than average precipitation. The proportion of slightly defoliated trees (class 1) decreased slightly between 2018 and 2019, whereas the moderately defoliated ones (class 2) increased from 12.5% to 23.3%. Moreover, the proportion of not defoliated trees decreased between 2018 (18.6%) and 2019 (15.0%).

In a first test we applied drone-based estimates of the photochemical reflectance index, the chlorophyll to carotenoid ratio, NDVI and determined canopy temperature by thermal infrared photography. We could relate some of the indices to tree water availability, reduction of photosynthesis and increase in non-photochemical quenching in 2019 and will test if these findings corelate with defoliation in 2020.

The study *Predicting Ozone Fluxes, Impacts and Critical Levels on European Forests* (PRO3FILE) aimed 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 were derived by quantifying ozone fluxes and applying multiple statistical techniques that considered confounding abiotic and biotic environmental factors.

Measured (ICP Forests, LWF, Sanasilva, Swiss NFI, NCEI) and modeled (Meteotest, EMEP, ECMWF) data from different national (LWF, Sanasilva, Swiss NFI) and international (ICP Forests, EMEP) networks, were combined to maximize sample size, diversity, temporal and spatial coverage along large gradients of forest types and environmental conditions.

For PODy and AOT40, we could not find consistence patterns between the different data categories and tree species. Such a model's variability could arise from various sources of uncertainties and data quality. In particular, for the temporal and spatial coverage, measured hourly meteorological data from ICP Forests seem to pose the main bottle neck for assessing ozone-growth relationships across European forests. The low numbers of 28 plots from 10 countries and 221 plots*years limit our comparison of the ozone-growth relationships obtained from the different categories. This low spatio-temporal coverage is partly due to the low quality of national data. More efforts should be invested into data aggregation, gap-filling and validation of hourly meteorological data from ICP Forests to allow dose-response relationships on a denser spatio-temporal coverage.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Burri S, Haeler E, Eugster W, Haeni M, Etzold S, Walthert L, Braun S, Zweifel R (2019) How did Swiss forest trees respond to the hot summer 2015? Die Erde 150(4):214-229

Gottardini E, Calatayud V, Corradini S, Pitar D, Vollenweider P, Ferretti M, Schaub M (2019) Activities to improve data quality in ozone symptom assessment within the expert panel on ambient air quality. In: Michel A, Prescher A-K, Schwärzel K (eds). Forest Condition in Europe: 2019 Technical Report of ICP Forests. Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). BFW-Dokumentation 27/2019. Vienna: BFW Austrian Research Centre for Forests. 104p.

Marchetto A, Waldner P, Verstraeten A (2019) Atmospheric deposition in European forests in 2017. In: Michel A, Prescher A-K, Schwärzel K (ed.) Forest Condition in Europe. 2019 Technical Report of ICP Forests, BFW Austrian Research Centre for Forests, Vienna, 26-35.

Rigling A, Etzold S, Bebi P, Brang P, Ferretti M, Forrester D, ... Wohlgemuth T. 2019. Wie viel Trockenheit ertragen unsere Wälder? Lehren aus extremen Trockenjahren. In M. Bründl & J. Schweizer (Eds.), *WSL Berichte: Vol. 78. Lernen aus Extremereignissen* (pp. 39-51). Birmensdorf: Eidg. Forschungsanstalt für Wald, Schnee und Landschaft

Schaub M, Vesterdal L, De Vos B, Fleck S, Michel A, Rautio P, Schwärzel K, Verstraeten A (2019) Trends and events – Drought, extreme climate and air pollution in European forests. 8th ICP Forests Scientific Conference, 11–13 June 2019, Ankara, Turkey. Proceedings, 41 pp. https://sc2019.thuenen.de/fileadmin/sc2019/SC2019_proceedings.pdf

Schaub M, Vesterdal L, Ferretti M, Schwärzel K, Rautio P, De Vos B (2019) News from the ICP Forests Scientific Committee (2019). In: Michel A, Prescher A-K, Schwärzel K (eds). Forest Condition in Europe: 2019 Technical Report of ICP Forests.

[1] Trees showing unexplained defoliation subtracting the percentage of defoliation due to known causes such as insect or frost damage.

Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). BFW-Dokumentation 27/2019. Vienna: BFW Austrian Research Centre for Forests. 104p.

Outlook

Future developments of the ICP Forests infrastructure

- Renewing of remaining meteorological stations and installation of new rain gauges and further soil water potential measurements
- Prototypes of an online data portal for near real-time access to selected datasets
- Establishment of a phenocam network
- Deep machine learning, image analyses and remote sensing

Planned research projects, expected results

- Post Doc project on remote sensing and image analysis
- Post Doc and PhD project on tree acclimation to hot droughts
- PhD project on isotope based tracing and modelling of soil water fluxes
- Preparation of the second Swiss forests soil condition survey on Level I and Level II plots in the years 2022 to 2025

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 since 2006 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 2019:

- Every year, on 599 Level I and 52 Level II observation areas, the "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 2020 and uploaded to the ICP Forests database.
- Needle-leaf samples were taken at 52 Level II observation areas in 2015, 2017, and 2019. Analyses are continuing and will be uploaded to the ICP Forests database in 2020.
- In the 52 Level II observation areas, all the measurements for the first 5 years on 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 II 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 uploaded to the ICP Forests database in 2020.
- 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 the meteorological stations will be uploaded to the ICP Forests database in 2020.
- 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 and 2019, water and needle-leaf and rash and soil 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

Level I

Monitoring studies have been conducted on a grid of 16x16 km and crown condition of 13838 trees in 599 Level I sample plots have been evaluated in 2019. The average needle/leaf loss ratio of all evaluated trees is 18.1%. The ratio of healthy trees (class 0-1) is 87.9% and the remaining 12.1% has a loss ratio of greater than 25 percent. The annual average needle/leaf loss increased by about 1.9% in comparison to the last year (2018).

The average defoliation ratio of broadleaved species is 19.0%. Common tree species with highest defoliation ratios are *Quercus pubescens* (25.8%), *Quercus libani* (25.0%), *Quercus coccifera* (21.9%), *Castanea sativa* (18.0%) and *Quercus petraea* (20.1%), respectively. In comparison to the year 2018, a deterioration (2.8%) in these species was observed. Among the less common broadleaved species (each of which are presented by less than 25 individuals), *Ceratonia siliqua*, *Juglans regia*, *Ostrya carpinifolia* and *Pistacia lentiscus* have a defoliation ratio of 25% or greater. While 86.9% of all broadleaved trees showed no or slight defoliation (class 0-1), 13.1% of them had defoliated by more than 25% (class 2-4).

The average defoliation ratio of coniferous species is 17.2%. 88.6% of all evaluated coniferous trees have a needle loss of less than 25% (class 0-1), and the remaining 11.3% of them have over 25% needle loss (class 2-4). *Pinus brutia*, *Pinus pinea*, *Pinus nigra*, *Juniperus* sp. (*Juniperus excelsa, Juniperus oxycedrus*, *Juniperus foetidissima*) have the highest needle loss among common conifers with defoliation ratios between 22.4% and 19.7%. As for pine species, defoliation ratios of *P. brutia*, *P. sylvestris* and *P. nigra* are 19.6%, 16.2% and 15.0%, respectively.

Among the biotic causes of damage, *Thaumetopoea* sp., *Tomicus* sp., *Rhynchaenus fagi*, *Mikiola fagi, Agelastica alni, Leucaspis pini and Cryphonectria parasitica* are the most pronounced species. Number of trees affected by *Thaumetopoea* spp. is almost the same in comparison to last year (2019). As in previous years, mistletoe (*Viscum alba*) is also among the leading damaging agents.

Level II

- Ozone damage was encountered in the Level II observation areas of 8, 12, 18, 29, 30, 51, 52 within the scope of air quality monitoring made in 2017, 2018, and 2019. In 2018, ozone loss was observed in the observation areas numbered 8, 10, 12, 18, 29, 30, 51, 52, 54. In 2019, ozone loss was observed in the observation areas numbered 8, 11, 12, 18, 29, 30, 51, 52.
- There is 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.

Outlook

Future developments of the ICP Forest infrastructure

- In 2015–2019, soil, litterfall, needle and leaf, deposition and soil solution working ringtests were entered and positive results were obtained. Analysis studies are continuing.
- The application for the soil working ringtest is expected in 2018-2019.
- 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 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 2019. 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. Vegetation surveys were undertaken across the sites this year.

2019 was both warmer and wetter than average. February was the second warmest since 1910 with record breaking daytime temperatures. Overall the spring and summer were very wet with double the average rainfall. In late June a heat wave saw annual maximum temperature records broken with a maximum reorded temp of 38.7 °C.

The main research focus in the UK continues to be the threat to UK forests from pests and diseases and their impact. Three percent of UK native woodlands are currently in an unfavourable condition due to pests and diseases with a cluster of issues to do with oak health having been identified in the South and West of the UK.

Major results/highlights

A major knowledge review of oak health was undertaken across the UK. Following this review as part of the ActionOak initative, ICP Forests monitoring methodology has been re-introduced at 85 oak plots from the original UK forest condition survey (1987-2007).

Data collected from UK ICP Forests plots was submitted under Article 9 of the National Emmissions Celings Directive (NECD 2016/2284) for the first time this year. BioSoil data was used in association with the UK National Forest Inventory to inform

England's national capital accounting and ICP Forests data underpinned nutrient sustainability decisions and guidelines for sustainable biomass extraction from conifer plantations in the UK's uplands.

Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Guerrieri R, Vanguelova E, Pitman R, Benham S, Perks M, Morison J, Mencuccini M (2019) Climate overrides atmospheric deposition in affecting spatial and temporal changes in forest water-use efficiency and nitrogen availability across Britain. Under review in Nature.

Quine CP, Atkinson N, Denman S, Desprez-Loustau M-L, Jackson R, Kirby K (eds) (2019) Action Oak Knowledge review: an assessment of the current evidence on oak health, identification of evidence gaps and prioritisation of research needs. Action Oak, Haslemere, UK

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.
- As part of the Action Oak initiative the Forest Condition Survey was re-introduced at 85 of the original UK oak plots from the 1987–2007 survey and will continue year on year.

Planned research projects, expected results

- Nutrient accounting
    - Nutrient budgets of all UK plots
    - Investigation of soil C and N change on organo-mineral soils
- DOC fractionation of soil solution to investigate effect of drought and rewetting on the carbon release from soils on the UK
- Deadwood volume, biomass, decay class and release of DOC under managed and unmanaged forest conditions
- Investigating the change in vegetation communities across forest plots using Ellenberg
- PhD studentship on forest management and N leaching to ground waters.

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United Nations Economic Commission for Europe (UNECE)
Convention on Long-range Transboundary Air Pollution (Air Convention)

International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

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Print product
ClimatePartner.com/12280-2009-1001

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Recommended citation
Michel A, Prescher A-K, Schwärzel K, editors (2020) Forest Condition in Europe: The 2020 Assessment. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. https://doi.org/10.3220/ICPTR1606916913000

ISSN 1020-3729 (print) ISSN 2702-5411 (online)
ISBN 978-3-86576-219-1 DOI 10.3220/ICPTR1606916913000

ISBN 978-3-86576-219-1
9 783865 762191